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ABSTRACT

This book expands on the argument for a new type of science curriculum for secondary schools. Instead of being based on each of the major disciplines as are almost all current science curricula, it is suggested that curricula should be conceptually organized around the Earth system, including the science methodology of the system sciences, and capitalize on the cross-cultural characteristics of science to establish greater understanding of the contributions of all cultures. The first several chapters of the book add additional support to Global Science Literacy (GSL) as a viable international basis for science curricula. The chapters describe the characteristics of Chinese culture and compare them to GSL characteristics, discuss research on science in an indigenous culture and the implications for GSL, and summarize research on science teaching in the field and its implications for GSL. Additional chapters describe the national science curricula of Taiwan, the People of the Republic of China, Singapore, Korea, Germany, and Spain and the conditions for implementing GSL in those countries. The last several chapters discuss experiences and programs for developing teachers of Earth Systems Education curricula and those based on GSL. (KHR)

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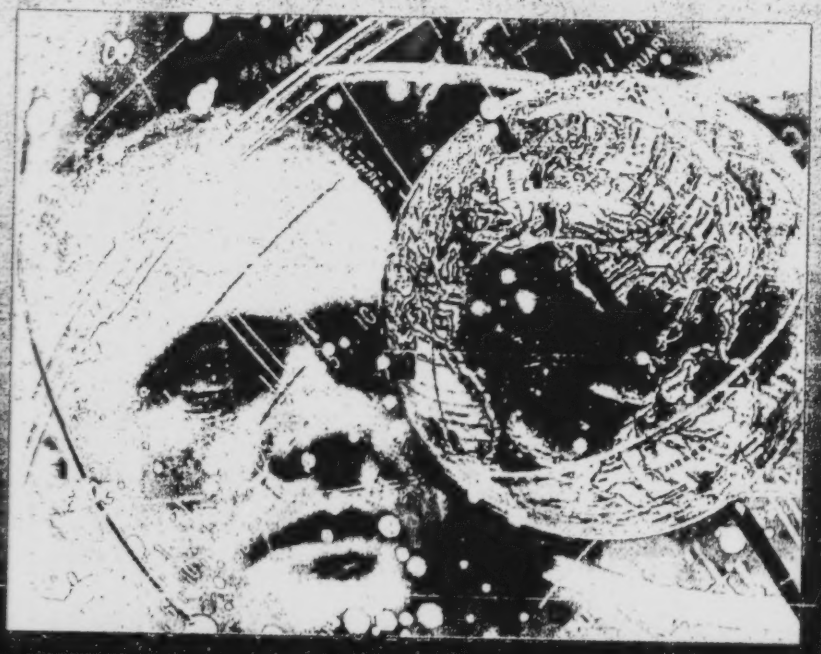

Earth Systems Education Program

The Ohio State University

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IMPLEMENTING GLOBAL SCIENCE LITERACY

Victor J. Mayer, Editor

Earth Systems Education Program

The Ohio State University

Columbus, Ohio, USA

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Some twenty people were involved as first or second authors of the nineteen chapters in this book. Three, including myself, are residents of Columbus; most are citizens and residents of other countries. Only five have English as our first language. To assemble a book under these conditions could be a very formidable task. Add to those conditions the fact that as a retired professor, I was unable (nor did I desire) to obtain any professional editorial help. Only Bill Gates, through his product of Microsoft Word, offered me assistance—and those of you who have had the misfortune of working in this program know the quality of that assistance.

Under such adverse conditions then, I have to credit the excellent work and cooperation of the chapter authors from twelve countries who contributed manuscripts. Our primary interactions have been over the Internet. Any criticisms I may have had of initial submissions were communicated through Email, as were the authors' responses. All of the chapters appear here in their final submission form. My editing subsequent to initial comments on content and language was only what was required to get each chapter into the final format with the Word program. A great deal of thanks, therefore, must go to the chapter authors for the excellent work they have contributed to this project.

Global science literacy has been an interest of mine over the past decade or more. In addition to the expected support from my University for my work on the concept, there have been a variety of other sources of financial and technical assistance. First is the National Science Foundation and its support of the conference held in 1988 in Washington, D.C. by the American Geological Institute and the National Science Teachers Association. This conference resulted in the rationale for the development of Earth Systems Education (ESE). The Foundation's subsequent funding of the Program for Leadership in Earth Systems Education to The Ohio State University and the University of Northern Colorado helped to further define the philosophy and structure of ESE. Following my retirement from The Ohio State University, Hyogo University of Teacher Education, Japan, provided support for my work on the initial expansion of ESE into Global Science Literacy during eight months in 1996. In 1998, the Fulbright Program supported research on GSL in the context of Japanese science education. In 2000, the Korea National University of Education supported an effort to acquaint Korean science educators and teachers with the philosophy and content of GSL. Finally, the Alphyl Memorial Fund, managed by The Ohio State University in memory of my parents, provided modest support for the development of the initial book, *Global Science Literacy*, published by Kluwer Academic Publishers in 2002 and for some of the development costs of this book.

Finally however, this book would not have been possible without the support provided by the institutions represented by the authors of the various chapters. I am very thankful to those institutions, mostly universities, and their faculties for this support.

VJM
Columbus, OH
March 2003

INTRODUCTION

GLOBAL SCIENCE LITERACY ELEMENTS

This book carries on a discussion begun in *Global Science Literacy*, published by Kluwer Academic Publishers in 2002. That book, edited by myself with contributions from 15 authors representing six countries, developed a theoretical and rational argument for a substantive change in direction of pre-college science curricula worldwide. It proposed that science curricula should be based on the subject that all of the individual science disciplines study--the Earth system and its environment in space. In Chapter One of this volume, I summarize the arguments for this position and add to the argument the contributions of systems thinking in developing students as problem solvers. I also contrast Global Science Literacy with Science, Technology, and Society as curriculum change efforts, one of the more popular recent efforts at science curriculum change worldwide. The following three chapters add additional support to the concept of GSL as an internationally appropriate basis for science curriculum development.

One of the arguments for GSL as a basis of science curriculum reform internationally, is that it represents the modern nature of science as an international and culturally consistent effort at attempting to understand Earth, the habitat of the human populations of all nations. In Chapter Two, Broadstock describes the philosophical attributes of Chinese culture and compares them to the nature of the investigative methods and resulting product of the systems sciences. She concludes that GSL as a curriculum construct has a much broader cultural consistency with Chinese culture as representative of Eastern cultures generally.

Riggs, in Chapter Three, describes his research with an American indigenous culture and the implications of the knowledge acquired by that culture for teaching science. Such indigenous knowledge, he argues, must be a starting point for teaching science in those indigenous communities. It provides a bridge between the indigenous culture and the culture of science. It can also, however result in conflict when the indigenous knowledge has a worldview that conflicts with the scientific worldview. He argues that the scientific worldview presented by system science can be much more amenable to those of indigenous cultures than is that of reduction science, and therefore help to provide a "border-crossing" into the culture of science.

Orion, in Chapter Four, emphasizes the importance of the field and field experiences for effective GSL curricula. He critiques past efforts at conducting research on the efficacy of outdoor experiences and then suggests a framework for future investigations. These first four chapters add to the arguments made in the earlier book for using Global Science Literacy as a basis for science curriculum revisions worldwide. It provides a more culturally consistent basis for teaching children about the word they inhabit and interact with.

IMPLEMENTING GLOBAL SCIENCE LITERACY IN NATIONAL CURRICULA

Chapter Five begins a series of chapters in which the implications of GSL for curriculum development in several different countries are explored. Chang describes the changes in the Taiwanese science curriculum and a series of Earth Systems modules that have been developed and evaluated. His evaluation of the modules supports our contention regarding the greater efficacy of GSL based curricula in non-Western cultures. Lee reports on research conducted in middle schools in Korea and the United States, comparing students' knowledge and attitudes toward environmental and earth systems concepts. He draws implications from this study for needed changes in the Korean science curriculum. Trend in Chapter Seven discusses the relation between geography and science curricula in the United Kingdom. He criticizes the current science curriculum as lacking in sufficient attention to the earth system, especially sad considering the extensive inclusion of related topics in the Physiography text devised and published by Huxley in 1880. He suggests that encouraging cross-fertilization between science and geography teachers and curriculum developers could assist in overcoming this deficiency in UK science curricula.

Yu, in the next chapter, relates the history of development in the People's Republic of China, politically, environmentally and economically, to the nature and deficiencies of the current science education system and draws conclusions regarding the relevance of GSL for improving China's ability to compete effectively in the global environment and to prepare citizens who are science literate. The authors of Chapter Nine report a survey of teachers in the country of Cyprus and identify the conditions under which successful implementation of earth systems courses could be accomplished in the Mediterranean Region. In Chapter Ten, Lillo analyzes the Spanish science curriculum and compares it with the GSL philosophy. He concludes with recommendations as to how changes must be effected in science teaching to accommodate a more international type of curriculum effort in Spain. In the following chapter, a group of authors describe the German situation in regard to the lack of earth science courses in the country and their project to provide research and curriculum materials to address that critical need. In Chapter Eleven the authors describe the science curriculum of Singapore and then go on to compare it to the tenets of GSL, suggesting elements of the latter that could be included in the Singapore curriculum to better prepare students in science literacy.

Only in the case of Taiwan has there been an attempt to include instructional materials based on GSL in national curricula. The authors of each of the other chapters provide information and analyses that should help curriculum planners within their subject countries to adapt the philosophy of GSL to any future restructuring efforts.

THE ROLE OF TEACHER EDUCATION IN EARTH SYSTEMS PROGRAMS

Perhaps the major problem in developing new curricula that are not discipline based is to prepare teachers for teaching those programs. Those attempting to implement integrated science curricula have many sad stories about their attempts to change undergraduate teacher education programs in colleges and universities in the United States to adequately prepare such teachers in science. How can we expect teachers to develop and teach a type of science that they have never been exposed to in their learning of science? Attempts to develop integrated science courses at the university level in the USA founder on the politics of well-established science departments of the various disciplines often funded on the basis of their course enrollments. There are a few universities that have reorganized their geology departments into Earth systems departments; Penn State and Stanford come to mind. Often, however, such reorganizations have little impact upon the disciplinary nature of the science courses offered--but they do offer hope. The next three chapters in this book are devoted to a description of efforts at developing integrated earth systems courses in two universities.

In Chapter Thirteen, authors representing the education and science units of the University of Aveiro in Portugal, describe their efforts to develop and implement an integrated global science course for elementary science teachers. Their conceptual framework is a good starting point for development of similar courses at other universities. Chapters 14 and 15 are written by professors of the University of Campinas, Brazil. They are based on research conducted at the university in earth science and science education. Chapter 14 is a discussion and review of the history of the science of geology and of geological education and of the nature of geological thinking and investigation. Through this discussion, themes for an introductory university course in earth science are identified and proposed. Their colleagues in the next chapter provide an extensive discussion of the unique characteristics of geology as a science and the importance of the geological view in both science education and pubic policy. They emphasize the importance of field experiences in establishing a sense of place, essential in geological thought. They conclude their discussion by describing a school-based research project in which they attempted to apply some of their conclusions in a teacher preparation program.

APPROACHES TO INSERVICE EDUCATION IN EARTH SYSTEMS EDUCATION AND GLOBAL SCIENCE LITERACY

Until universities can be reformed and induced to offer broadly conceived science courses, organized about conceptual products rather than the requirements for majors in separate disciplines, curriculum reformers must depend upon in-service education of teachers to provide the bases for the support of curriculum innovation. The final chapters of the book review some of the efforts at providing in-service programs that are consistent with the philosophy of Global Science Literacy.

Myers, in Chapter 16, describes an effort to develop and offer an on-line course in Earth Systems Science that not only updates teachers' background in the

science, but also reinforces their ability to offer investigative experiences to their students. System science methodology is one of the critical additions that GSL can make to science programs. Kim, in Chapter 17 relates abductive reasoning to earth systems methodology and suggests ways in which science educators can prepare pre-service teachers to implement this type of investigation in their classes. Similar methods can also be used in in-service teacher programs. In Chapter 18, I apply my experiences with summer and in-service teacher institutes in Earth Systems Education to the development of model in-service programs for Global Science Literacy. I include valuable suggestions for the development of such programs following the successful experiences at The Ohio State University in the early 1990s.

The final chapter, by Nir Orion of Israel, expresses a great deal of frustration regarding the conservative nature of the science education and education establishment in Israel. It is based on his decade or more of attempting to help teachers implement new approaches to science curriculum and teaching, many based on models similar to GSL. The chapter is included here because his concerns are also mine. Mine are based on some 40 years of involvement in curriculum reform efforts in the USA and more recently on work in several Asian countries. What he says about the responsibility for failure in reform can be duplicated in almost any country. It is a problem of failure of the political establishments to provide the necessary resources, of the education leaders to actually understand and believe in the reforms they advocate and of the science educators who should know better. It is always easy to blame the teachers, but they are trapped in a room and in a style of teaching that is reinforced in subtle and often not so subtle ways. They are trapped by parent expectations and by colleges' expectations. Seldom do they have the luxury of thinking about the needs of the learner and the needs of a democratic society for a scientifically literate citizen. This is a rather depressing conclusion for a book on science curriculum change. However we hope that this book and its predecessor *(Global Science Literacy)* can help to provide some light to change this situation. We trust that the new science education leaders can be more effective than the old—that some will read these books and take to heart their message—and that some day in the not too distant future REAL science curriculum and teaching change will occur in countries throughout the world.

REFERENCE

Mayer, V. J. (Ed.) 2002. *Global Science Literacy*. Dordrecht: Kluwer Academic Publishers.

CHAPTER 1: GLOBAL SCIENCE LITERACY: A THEORETICAL AND CONCEPTUAL FOUNDATION FOR SCIENCE CURRICULA

Victor J. Mayer, The Ohio State University, USA

1. INTRODUCTION

This chapter is being written in the wake of a most devastating attack on the world community; the destruction of the World Trade Center in New York City and the associated terrorist attacks on Washington, D.C. Americans have suffered the most, but also killed have been many citizens of England and other countries around the world. The attack was carried out by individuals holding a very conservative fundamentalist Islamic theology—a belief system held by small minorities in some of the very poorest countries in the world. In these countries radical leaders have capitalized on the suffering caused by poverty contrasting the suffering of their populations with the well-off populations of the wealthy developed countries--the targets of the attack. Following this attack, President Bush declared an all-out war on terrorism, seeking to root out the perpetrators. In this war, sophisticated military and intelligence gathering technology was used to bomb and destroy the military potential of the Taliban leaders of Afghanistan, the government that hosted the Al Qaeda terrorist network. American forces on the ground were small in number, but well trained to seek out and destroy the terrorist network, hiding in caves and among the innocent civilian population.

What is the relevance of this in the introductory chapter to a book on science curriculum development? Earlier we have made the case that the end of the Cold War has brought new imperatives to the conduct of science and thus also to the nature of science education in our schools (Mayer and Fortner, 2002). We reasoned that to serve democratic countries effectively, environmental and social problems, which have evolved in part from the use of science to produce the technology to win the hot, cold and commercial wars of the 20th century should, and we believe, will become the major objectives of publicly supported science. This will require a change in the focus of the science establishment from its concentration on the physical sciences and their methods, to an accommodation with the system sciences and their methodologies. In turn, it will be important for the science curriculum to accommodate these changes in the focus of the science enterprise. We suggested Global Science Literacy (GSL) as a curriculum philosophy for the Post Cold War era. A philosophy that, if followed in the development of science curricula, would be consistent with the changing nature of publicly supported science and consequently help to prepare citizens to influence and construct a peaceful and sustainable future.

With a new conflict being fought against terrorism, it might be reasonable to assume that this argument is now null and void. However, I believe that a careful analysis of the root causes of the terrorism will lead to a reinforcement of the need for a new type of science curriculum, one based on the philosophy of GSL. It has been argued that one of the major sources of support for terrorism is the poverty

resulting, at least in part, from the various wars of the past. Whether true or not, the impression raised among many of the poor is that their lot is a result of a great disparity in wealth caused at least in part by the exploitation by the developed nations of those nations that are economically poor but labor and mineral rich. Such feelings can be stimulated and then employed by terrorist leaders in marshalling support and gaining participants for their activities.

Another factor in the spread of terrorism is the lack of understanding and acceptance of other cultures. According to many news reports, the *mossad* schools in some of the Islamic countries focus on a hatred of other cultures, instead of providing accurate and unbiased information about them. In Mayer and Tokuyama (2002), the first chapter of our book entitled *Global Science Literacy*, we make the case for science as a curriculum component that can help to enhance cultural understanding among nations and sub cultures within nations. When it is expanded with objectives from the social studies curriculum area of global education, it can provide an essential component of educational programs world wide that can enhance global understanding among the citizens of democratic countries. It can also help to influence, through citizen participation, more informed political and economic policies of the developed countries toward those less developed. Global Science Literacy, therefore, if used as a basis for science curriculum development in the countries of the world, can be one small influence in improving people's lives and the understanding and appreciation of other cultures. In this way it can contribute to a peaceful world by helping to remove some of the root causes of terrorism.

2. ESSENTIALS OF GLOBAL SCIENCE LITERACY

GSL differs from the standard science curriculum, as it exists in most parts of the world today, in several ways:

1. It is conceptually organized rather than organized by science discipline.
2. It accepts the idea that there are aesthetic incentives to the understanding and appreciation of the subject of all science, the Earth system.
3. It incorporates the science methodology and thinking of the system sciences as well as that of the physical sciences.
4. It recognizes the role of science in society by incorporating objectives from the social studies curriculum construct of global education thus capitalizing on the unique advantages of science and the science curriculum in promoting cross cultural understanding.
5. By incorporating the systems science concept and thinking, it accommodates Eastern thinking and worldviews thus providing a wider international basis and cultural acceptance for the science curriculum.

2.1. *Conceptually organized*

First, GSL curricula are conceptually organized rather than being organized by science discipline. That is, content is organized around the concept of the Earth as a

system, often with the various Earth system cycles as components of the organizing framework (Orion, 2002). Since the Earth system and its environment in space are the subjects of study of all disciplines of science, content from the various disciplines is woven into this framework as it helps to explain the functioning of Earth processes. This focus for the organization of content brings science to the immediate interest and experiences of the learner. Instead of having to learn abstractions of natural occurrences, often confined to a laboratory setting, students apply basic science understandings within a familiar context, their habitat, a context that is often of aesthetic as well as intellectual and practical interest to them. We have used an unique organization of the content standards developed by the National Research Council of the National Academy of Sciences (NRC, 1996) (See Appendix B) and combined them with the seven Earth Systems Education Understandings (Mayer and Tokuyama, 2002) to illustrate and guide the nature of the science content development in GSL curricula (See Appendix A for the seven Understandings).

2.2. *Incorporates aesthetics*

The first Earth Systems Understanding is "Earth is unique, a planet of rare beauty and great value". This understanding was included at the insistence of scientists participating in a weeklong conference to define those basic understandings to be included in science curricula (Mayer and Armstrong, 1990). They argued that one of the reasons they pursued a career in science was that they found beauty in the Earth system. It could have been sunsets, the aurora, plants, and animals, any of a wide variety of natural features that they found aesthetically pleasing and stimulating. This was a major incentive for them to follow a career that would lead them to a deeper understanding and valuing of Earth. Since this is true for scientists, science educators should also see the value of Earth aesthetics as a part of the science curriculum. By including it as a context for teaching about Earth processes, science teachers can attract a broader variety of students to an interest in science. For this reason, we believe that it should be included in science teaching and have thus included it as an understanding of ESE, the science curricular basis for GSL.

2.3. *Incorporates system science methods*

The science curriculum as it exists in almost all secondary schools throughout the world, emphasizes the content and methodology of the physical sciences. This elevates the controlled experiment to the highest levels of science "quality" in the minds of the teachers and their students—and in fact the citizens that have benefited from quality education during their college and pre-college educational experiences. This emphasis upon "experiments" as being the hallmark of good science went so far during the days of the United States' National Science Foundation curriculum projects in the 1960's and 1970's that the only widespread curriculum effort in the Earth sciences, the Earth Science Curriculum Project (ESCP), used controlled experiments in its textbook. Many Earth science teachers were treated to the experience of a class of 30 children shaking pieces of rock in metal coffee cans

during an effort to determine erosion rates in a contrived "experiment" that controlled for time and rock type. Ignored, even in this curriculum, were the methods of scientific investigation typically used by the geologist and ecologist. Frodeman (1995) in his seminal paper has described these methods as used by geologists. Mayer and Kumano (2002) in reviewing the characteristics of the system sciences, such as geology, have called these methods "systems science methods". It is these methods that Darwin used in developing his theories of evolution and natural selection, and they are the methods that are informing us about the reality of global warming. They are also the methods of science that will be most useful in future attempts at solving some of the environmental and social problems we have inherited from a century of war and economic conflict. GSL incorporates this type of science methodology as a cornerstone for modern science education programs.

2.4. *Integrates objectives of global education*

The nature of science investigation is such that it promotes inter-cultural cooperation and understanding. Its subject, the Earth system, is one held in common by all scientists the world over. The methodology of science facilitates communication among its participants, despite differing cultures and languages. These conclusions about the international nature of science as it is practiced can be verified by examining the authorship of science research studies published in most scientific journals. Mayer and Tokuyama (2002) applied this understanding of the cross-cultural nature of science and combined topics of science curriculum from the American national science standards with objectives of the social studies curriculum area of global education to formulate the content structure of Global Science Literacy (See Appendix B). Global education is a curriculum construct that seeks to develop a global perspective among students. Hanvey (1975) identified five elements of a global perspective—perspective consciousness, state of the planet awareness, cross-cultural awareness, knowledge of global dynamics, and awareness of human choices. These are understandings appropriate for inclusion in science curricula—in fact, supported by the very nature of science, its methodology and its content.

2.5. *Accommodates aspects of Eastern thinking*

The concept of the Earth as a system with humans as a subsystem is one that contrasts with the Western idea of the distinctness of man from the natural world—the philosophy in which modern science was founded. This Western idea led to the ascendancy of the physical sciences as a tool used in protecting us from the natural world and in wresting natural resources for our use. Science was useful since it enhanced our ability to utilize the resources of the natural world in our daily activities. This contrasts with the Eastern concept of people as integral parts of nature, depending upon and existing in harmony with natural processes (Mayer and Tokuyama, 2002). The system science methodology also reflects this type of thinking. Its conceptual schemes include the human being as an integral part of the life system and illustrate the interrelationships of the human with other Earth

systems. Thus GSL, incorporating system science methodology and with content structured around the concept of the Earth as a system, presents a curriculum in science much more in harmony with Eastern thinking than one founded entirely upon the thinking and philosophy inherent in the physical sciences. Therefore, students from both Western and Eastern cultures can be culturally comfortable with science curricula that use GSL as their philosophical and developmental basis.

3. GLOBAL SCIENCE LITERACY INCORPORATES SCIENCE METHODOLOGIES THAT ENHANCE HIGHER ORDER THINKING SKILLS

Wilson and Livingston (1996), in their chapter entitled "Process Skill Enhancement in the STS Classroom", surveyed the science education literature starting with the 1932 *National Study of Education Yearbook* through the AAAS *Benchmarks* (1993) and the National Standards (1996) to arrive at their conclusion that:

> Science education has always articulated a need to have students develop their thinking and reasoning skills. The processes that scientists use have been seen as important to impart as "learnings" in science courses. (p. 59)

Most science educators have believed that science can uniquely serve the curricular objectives of developing critical thinking among pre-college students. Thus, there has been an ongoing effort over the years to structure science curricula to be "activity-oriented", "investigative", "process oriented". In doing this, however, educators have relied on a single stereotype of the "nature of science" and its methodology. Thus the broad nature of science and its methodology has been poorly represented in science curricula.

The late Stephen Gould (1986), Agassiz Professor of Zoology at Harvard University, described our science education and its methodological emphasis as follows:

> Most children first meet science in their formal education by learning about a powerful mode of reasoning called "the scientific method." Beyond a few platitudes about objectivity and willingness to change one's mind, students learn a restricted stereotype about observation, simplification to tease apart controlling variables, crucial experiment, and prediction with repetition as a test.

He goes on to point out that science curricula fail to provide a background in an essential component of the system sciences, that of history. In fact, they condition students to feel that a science that focuses on description and one in which experiments cannot be conducted is not science at all.

> These classic "billiard ball" modes of simple physical systems grant no uniqueness to time and object--indeed, they remove any special character as a confusing variable--lest repeatability under common conditions be compromised. Thus, when students later confront history, where complex events occur but once in detailed glory, they can only conclude that such a subject must be less than science.

Gould effectively portrays the type of science presented in American classrooms.

Gould's characterization of school science is implicit in the AAAS (1993) grades 6 through 8 Benchmark for the "nature of science":

> If more than one variable changes at the same time in an **experiment**, the outcome of the **experiment** may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations. (p. 12) (emphasis added)

This characterization of science methodology as "experimental" and the consequent need to control variables is even more apparent in the National Standards (1996). In the section on designing and conducting a scientific investigation it is stated that:

> Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables (p. 145)

And:

> Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an **experiment.** (p. 175) (emphasis added)

Although the term "experiment" does not appear in the standards statements as such, it is used extensively as an alternative to "investigation" in the discussions of the inquiry standards.

This focus on "experimental science" extends across the Atlantic as well. In the report entitled "*Beyond 2000*" (Millar and Osborne, 1998) British science educators recommend that the ideas about science in secondary school should include:

> how to design a simple investigation of the relationship between two variables, keeping other variables and factors constant.

Thus the impression given to the reader of these influential publications is that the only acceptable type of science methodology is the controlled experiment of the physical scientist. Left out of the *Standards*, the *Benchmarks*, and indeed all science curricula worldwide is a treatment of the predominant methodology of the earth and ecological scientists--what we have termed, system science methodology (Mayer and Kumano, 2002).

If an important objective of science teaching is the development of thinking skills as suggested above, then why does the science curriculum focus on a methodology that is useless to the average citizen? How often can you or I solve a problem in our daily lives by thinking through a controlled experiment? Certainly the attention paid to the variety of variables in our problem assists us in our endeavors. But, we can seldom run a controlled experiment to gather data to help us think through or solve our problem. It is our contention that the system science approaches, however, **are** useful to the average citizen. Thus they should be given

status in any science program in which problem solving and thinking skill development are important objectives.

Resnick (1987) described the characteristics of higher order thinking as:

1. non-algorithmic (the path of action is not specified in advance);
2. often complex (the total path is not mentally visible from any single vantage point);
3. yielding multiple solutions (each results in certain costs and benefits rather than unique solutions).
4. involving nuanced judgment (and interpretation).
5. applying multiple criteria (which sometimes conflict with each other).
6. involving uncertainty (not everything needed will be known).
7. involving self-regulation of the thinking process ((it is not guided at each step by someone else).
8. imposing meaning (develops order among apparently disorganized information).
9. requiring effort (considerable mental work is necessary).

Few of these characterize the thinking involved in the experimental sciences. System scientists such as geologists, however, can identify most of these characteristics, in the reasoning procedures they use.

In Mayer and Kumano (2002), we review Frodeman's characterization of the system science methodology used by geologists:

> Frodeman (1995) characterizes the reasoning methods of the geological sciences as **hermeneutic** or interpretive, and **historical**. The geologist applies this type of reasoning to the various characteristics of an outcrop, "judging which characteristics or patterns in the rock are significant and which are not". It is apparent that in this process, preconceptions will be involved in making judgments. Thus, the data used by the geologist will be meaningless to the uninitiated until "the geologist introduces concepts for 'seeing' the rock". In a sense, this type of reasoning may be a tool in the development of all human knowledge, even in the 'objective' physical sciences (Eger, 1992). However, it is basic to the system sciences. There are three characteristics of hermeneutics that play fundamental roles in geological reasoning. They include the "hermeneutic circle--the fore restructures of understanding, and the historical nature of knowledge". The hermeneutic circle is a process of back and forth reasoning where earlier conceptions are used as new data are presented to continue to build a conceptual structure. Thus, "wholes at one level of analysis become parts at another". This is the means by which all understanding progresses. The second point, fore structure, relies upon the scientist's preconceptions and foresight. Preconceptions are the theoretical basis upon which the interpretation of data is approached and foresight the "presumed goal of our inquiry and our sense of what will count as an answer". The final characteristic includes the tools and sets of procedures or practices that are brought to the collection and processing of data. The nature of these tools and procedures also shapes the types of data acquired and their interpretation. This will include the discussions and critiques of colleagues as interpretations are developed or discussed in the literature. As these interpretations are accumulated over time, "the body of scientific knowledge comes to have a strongly historical component".

Frodeman, in his preface to a collection of essays entitled *Earth Matters* (2000), states that the Earth sciences provide a model of reasoning that is more

attuned to the realities that we face in our daily lives than do the physical sciences. The Earth sciences have a distinctive method of reasoning;

> ...that is deliberative rather than simply calculative, interpretive rather than purely factual, and historical rather than experimental—again, like our own personal and public lives. (p.ix)

He further argues the appropriateness of the system science methodology as a model for reasoning since knowledge can no longer be treated as discrete packages of information. Now and in the future, disciplines will need to be able to indicate how their information relates to that of other disciplines in a political and logical manner that fit the concerns of society

> The Earth sciences, then, provide us with an image of the challenges that all disciplines will face in the twenty-first century. (p. x)

Frodeman (2001) in his talk presented to a symposium on secondary science education concludes that:

> Scientific reasoning is too often caricatured as a cookbook method that provides us with infallible answers. This misrepresentation damages both science and culture when the inevitable disappointment sets in. The scientific reasoning process typified by geology offers an account of reasoning more applicable to the uncertainties and complexities of our lives. We are seldom in possession of all the data we would like for making a decision, and it is not always clear that the data are unbiased or objective. We are forced to fill in the gaps in our knowledge with interpretation and reasonable assumptions that we hope will be subsequently confirmed. Thus, the methods of a hermeneutic and historical science better mirror the complexities we face as historical beings. (p. 231).

In our opinion, it is crucial that the systems science mode of thinking become an important component of all secondary school science curricula, and especially those that claim to develop higher order thinking skills. Not only will this serve our students and future citizens well in their life long endeavors, it will also help to correct the misconceptions about the nature of science that concern Frodeman.

If science curricula are, in fact, to assist in the development of critical thinking skills among their users, then it is imperative that they be restructured along the lines we have suggested in providing a philosophical foundation for Global Science Literacy. They need to include as a major component, activities that exemplify the system science methodologies.

4. IS GSL SIMPLY A VERSION OF STS?

Occasionally during talks on GSL, a member of the audience will make an observation that GSL seems to be a version of Science/Technology/Society (STS). Although there are surface resemblances, particularly in reference to the learning environments and the inclusion of environmental content in the two approaches, I believe there are several fundamental differences. To assist in clarifying what we

mean about the nature and basis of GSL it might be illustrative to compare the two approaches to science curriculum, starting with the genesis of the two models.

4.1. Impetus for STS in the USA – economic and military needs

In the mid 1980's I was a member of the Board of Directors of the National Science Teacher's Association. This was the period when the Reagan Administration was expressing deep concern about the quality of education in the United States, particularly the education in mathematics and science (National Commission on Excellence in Education, 1983).). This concern arose because of the recession in the American economy and the dominance of Japan in global commerce at the time, and the administration's efforts to develop a missile defense, popularly called "Star Wars". The administration decided that to enhance our economic position in the world and to successfully purse the advanced technology implied by "Star Wars" which it felt was needed to counter the USSR efforts in the cold war, it was necessary to improve our science curricula and science teaching. The Board, comprised of science teachers and college science educators, was concerned that the science education community participate in the discussions about science education policy and assist in determining the nature of future science education programs. In response to this concern, one of my colleagues on the Board brought a draft of a position paper on science/technology/society to the Board for approval. After revisions and rewriting, the position statement was approved. In 1990, much of the content was included in the lead position paper published by the association (National Science Teachers Association, 1990). This was one of the attempts to bring the concept of STS to the American science education community. It reflects the rationale for the introduction of STS to the American community and its promotion by science educators. Although not native to the USA, STS provided science educators a new rationale for the revision of science curriculum and teaching that would reflect the national priorities in science and commerce of the administration.

Subsequent to this period of economic stagnation in the USA that saw the rise of the STS movement, a similar history occurred in Japan. It began an economic decline into recession in the early 1990's as the American economy improved, replacing Japan's as the strongest in the world. Science educators from Japan looked to Europe and the USA for ideas for the improvement of their science education programs, which they also saw as an engine for economic improvement and the development of the technical manpower base it would require. STS seemed to be a possible solution with its emphasis upon constructivist learning environments, environmental concerns and technological proficiency (Nagasu and Kumano, 1996). STS has also become a powerful orientation within the science education community of South Korea, a country that also encountered economic problems during the latter half of the 1990's.

4.2. *Critiques of STS*

One of the justifications for STS is the attempt to make science more relevant to the student. By employing the uses of science in technology and their impact upon society as themes, it is hoped that students will see science as being more related to their lives and thus exhibit a greater interest in learning science (Shamos, 1995, p. 140). Roy (2000) suggests that the science curriculum needs to be extensively revised to incorporate technical topics at all levels. He suggests that applied science should be used to introduce formal science instruction. Thus students would see science more directly as a part of their lives and better prepare them for our technical society.

I would question this assumption based on my junior high school teaching experience. This was before all of the NSF projects to redesign science curricula in the early years of the Cold War. It occurred in the early 1960's in a suburban Denver school. The ninth grade science curriculum used such technology as the internal combustion engine, the Frasch process for obtaining sulfur from underground deposits, the Bessemer process for producing steel and other technical applications of science processes, including a variety of levers. Studying these technical applications of physical science principles failed to elicit any interest among my students, either in the technology, or in the science behind the technology. I had much better success generating interest in science in my earth science classes by drawing upon the geological and topographic features of the Front Range and the plains, both visible from the school yard, and their practical and aesthetic features.

Shamos believes that a science program based in technology offers a route to technology education rather than science (p. 141). He further believes that:

> Another flaw in the STS movement is the impression conveyed by its title that STS is intended as a science curriculum. In fact, science, as it is normally understood, comes off a poor third in the STS hierarchy with the societal aspect, perhaps better characterized as a form of social studies, being its primary function. Science process skills, for example, as well as a mastery of science content should be de-emphasized in STS, according to some leaders in the field (p. 146).

There does seem to be a certain amount of confusion, perhaps even misunderstanding, regarding the nature of science and its relationship to technology in this movement. In relating the ways in which to describe the relationships between the two, Zuga (1996) states that they are symbiotic "two sides of the same coin". She considers science as the branch of inquiry for technology and as the impetus for advanced technological development (p. 231). Cheek (2000) discusses the confusion about technology as "applied science," apparently Zuga's argument. He points out that in many cases, technology is developed with little if any scientific basis in understanding and that many people in science education wrongly portray technology as "applied science" (p. 170).

4.3. *History of GSL*

The genesis and history of GSL is provided in some detail elsewhere (*Global Science Literacy,* 2002). Briefly, it was initiated in 1988 subsequent to a conference

held in Washington, D.C. The weeklong conference, sponsored by the American Geological Institute and the National Science Teachers Association with support from the National Science Foundation, included as participants some 20 scientists and 20 science teachers and science educators. Its final report defined the content and approach to be used in future earth science courses (Mayer and Armstrong, 1990). Presented at the conference by one of the participants from a NASA contractor, was the report of the Earth System Science Committee (1987). It provided a basis for many of the decisions made there and subsequently in developing the Earth Systems Education Program at The Ohio State University. In 1990, the National Science Foundation provided support for a five year long Program for Leadership in Earth Systems Education at The Ohio State University and the University of Northern Colorado. The 200 teachers and administrators participating in this program helped to provide the details for the final format of Earth Systems Education (ESE) incorporated in the curriculum guide, *Science is a Study of Earth* (Mayer and Fortner, 1995). This program and its report were used in the development of a number of Earth Systems Education Programs at the middle school and high school level.

In 1996, I spent almost eight months as senior researcher in the Global Education Program at Hyogo University of Teacher Education, Japan. Working with colleagues at the university, we developed the concept of Global Science Literacy. GSL used the ESE construct as the science curricular basis for developing the philosophy and characteristics of an international version of science literacy. One of the basic ideas is that science is an ideal curricular medium for promoting global understandings of culture. Through combining objectives of the social studies curricular effort of global education (Merryfield, 1997) and integrating its philosophy with that of ESE, the GSL construct was achieved (Mayer and Tokuyama, 2002).

In contrast to the history of STS, GSL was developed in the post-Cold War era. It looks to the future challenges of science and science curriculum in an era of social unrest and environmental change. It is not directed toward the use of technology in commercial or military developments but only the uses of technology for expanding our knowledge of the Earth system we all share.

4.4. *Comparison of STS and GSL*

Aikenhead (1994), after reviewing a number of writers on the characteristics of STS curricula, suggests that their views of the content of STS curricula center on,

> ...an interaction between science and technology, or between science and society, and any one or combination of the following:
> - A technological artifact, process, or expertise
> - The interactions between technology and society
> - A societal issue related to science or technology
> - Social science content that sheds light on a societal issue related to science and technology
> - A philosophical, historical, or social issue within the scientific or technological community. (pp. 52-53)

He then uses this definition to describe the structure of STS curricula.

Cheek in his 1992 survey of documents concerning STS (2000) found only six points of general agreement as to the nature of STS:

1. Raise levels of awareness regarding STS issues.
2. Emphasizes the general interactions among science, technology and society.
3. Incorporate ethics and values considerations.
4. Increase student understanding of the application of technology.
5. Promote decision-making skills.
6. Involve students in local community action. (p. 173)

Only one of these, item 5, might be typical of "traditional" science curricula. His survey was very extensive.

Despite these two reviews, there does not seem to be a great degree of agreement as to the typical content of STS curricula. I did a "quick and dirty' analysis of information that has evolved since Cheek's 1992 survey to see if I could obtain more detail. To do this, I have used several sources of information on STS. Since one of the most prominent proponents of STS in the United States has been Robert Yager I used chapters from the book that he edited (1996). I've also reviewed chapters in the books edited by Solomon and Aikenhead (1994) and Kumar and Chubin (2000). Finally, I also used Shamos (1995) and his critique of scientific literacy to try to distill the essential characteristics of STS. I have then listed several categories that are fundamental to GSL in the first column of Table 1, and attempted to identify aspects of STS that fit into those categories and listed them in the second column. I then matched them to the characteristics of GSL in the last column of Table 1.

Table 1. Comparison of STS and GSL characteristics

CATEGORY	STS MODEL	GSL MODEL
Science methodology	Not emphasized but decision making skills are a focus	Incorporates both systems and experimental science methodology as a basic core
Science content	Science concepts chosen from disciplines on the basis of their social or technical applications. Objective is to teach students 'about' science.	Uses a systems view of natural processes in organizing concepts; non-disciplinary; conceptually organized. Objective is to involve students in science.
Relationships between science and society	Usefulness of science to society through its technical applications Impact of technology on society and its social structure The role of science in society	Science as a model for facilitating intercultural communication and understanding Implications of science knowledge on philosophical foundations of society

Relation of science to technology	Science as a basis for technical developments Technology as applied science	Technology provides useful tools for discovering more about the Earth system
Environmental content	Environmental consequences of using technology Study of environmental problems	People and their activities are interacting components of the Earth system Understanding sustainable resource development and use from a systems perspective
Aesthetics	Not included	Use of aesthetics as a context for instruction about the earth systems and for eliciting student interest in science
Learning environment	Constructivist learning approaches	Student oriented learning approaches such as cooperative learning and field and Internet experiences
Cultural Perspectives	Functions from a Western world view	Systems conceptual structure and thinking accommodates Eastern as well as Western world views

I have found it difficult to obtain a consistent view of the nature of STS for the comparison made above. Thus I am sure it is open to criticism and change. In retrospect, this vagueness of definition may be the power of STS in that it is open to a wide variety of interpretations depending upon the particular needs and abilities of a given school and school system. Perhaps those that see GSL as a type of STS formulation are therefore correct in their assumption. We do insist, however, on the characteristics that have been defined briefly here and more extensively in Mayer, (ed., 2002). If a program does not meet all of the characteristics so defined, then we would not consider it as a GSL program.

From my review of the STS literature, I have concluded that those advocating STS have given up on the power of science for improving student understanding of the world and for eliciting their interest in science. Instead they have focused on the role of science as one of the bases for technology, and see the science curriculum as a way of using technology as a foundation for teaching students ABOUT science and its role in society, a position that Shamos (1995) articulated.

I frankly think it is too early to give up. As we have documented earlier, science in its breadth and glory has never been given an adequate chance in the world's science curricula. The beauty and fascination of nature has all to often given way to dry classroom discussions and laboratory experiments where it is reduced to a few general laws and equations. The STS approach seems to be a prescription for

using the limited time allocated to science instruction for teaching about technology (much of which is not the result of the application of science knowledge) and about social structures (the domain of the social studies curriculum in American schools). Why should we give up time for science teaching that is already at a premium? From my perspective it would be better for science teachers to work cooperatively with social studies teachers to develop quality efforts at including content relating to the influence of science and technology upon society within their curricula. After all, they are the teachers who are trained to teach about the nature of social issues and structures. Similarly, science teachers might cooperate with those trained in technology education to ensure that any science knowledge basis for relevant technologies is adequately covered in their technology curricula. The science teacher could then bridge from the science content appropriate for the science curriculum to that in either the social studies and/or the technology curricula. Thus a more powerful and authoritative treatment could be provided the student in these cross-disciplinary issues. This would leave the time given to science available for students to conduct those system science investigations that could enhance their critical thinking skills, help them learn the philosophical bases that science has provided for understanding their place within our world, and enhance their appreciation and valuing of their fascinating and beautiful world. It would seem to me that by insisting on including social and technical content in science curricula we are demeaning the efforts and the abilities of our colleagues from these other curricular areas.

We feel that it is important that science programs designed for the current and future needs of the global society we are now entering follow closely the ideas about science curriculum presented in our advocacy of GSL. Most are not new. Most, such as the orientation toward student involvement in meaningful science activities, have been part of science education since the time of Dewey, if not before--certainly during the post World War II and Cold War efforts at the improvement of science curricula exemplified by the National Science Foundation funded projects in the United States and the Nuffield Foundation funded efforts in Great Britain. Our advocacy of GSL is a call to recognize the power of science in the curriculum to create understanding and appreciation for our Earth system, to facilitate international understanding, and to realize the effectiveness of its methodology broadly represented in helping to solve problems on a personal, local, national and international basis.

5. DEVELOPING A RESEARCH AGENDA

Global Science Literacy is a new concept for the basis of science curricula at the secondary and earlier levels of science curriculum and teaching. As such, there are a number of issues that require the attention of the research community in science education and among the philosophers of science.

5.1. Philosophy of science issues.

Almost no attention has been paid to the nature of investigation in the system sciences. Apart from Frodeman, we have discovered no philosophers who have addressed this issue, albeit there are several geologists in the history of geology who have attempted to describe their thinking processes. The great, great bulk of writing and thinking about the nature and philosophy of science is actually about the nature of physics, a very limited perspective held by the history and philosophy of science communities. Frodeman has provided an excellent analysis that can help science educators in implementing the methodology of systems science in the secondary school classroom. It would be very beneficial, however, if there were additional minds paying attention to the nature of investigation in those sciences. This would help to refine and validate the conclusions offered by Frodeman, and assist science educators in understanding a very complex aspect of thinking. Such additional analyses would also help to firm the implications of education in system science thinking for those interested in research on the development of critical thinking in students—the relationship between elements of system science methods of investigation and the characteristics of critical thinking identified by researchers in that field.

5.2. Conceptual organization of curricula.

It is one thing to say that we should abandon the disciplinary focus of current science curricula but another to actually develop such curricula as those who have attempted to develop integrated science curricula have found. How can we throw off the mental chains of our training in geology, physics, chemistry or biology and develop sequences of instruction that do not simply represent fragments of those disciplines? A few years ago I attempted to write the science portion of an elementary science methods book using an earth systems education format. I found myself with chapters on the biosphere, lithosphere, atmosphere, etc--essentially, a disciplinary approach. Using this format, however, I was able to integrate within the various earth systems what I thought to be the essential concepts and ideas from each of the major science disciplines. Another area of needed research, therefore, is the development and classroom testing of models of curriculum organization. Orion (2002) has started on this process, albeit in the context of the Israeli lower secondary school earth science curricula.

5.3. Implementing system science methodology.

How can instructional sequences be developed that provide practice in the thinking strategies of the system scientist? A great deal of research, especially in physics education, has been devoted to the controlled experiment and its use in the classroom, but very little, to my knowledge, in the formulation of instruction based on system science methodology and the testing of its viability in the average pre-college classroom. Some of the work on the learning cycle may be applicable here in

expanded form. See the chapter by Chan-Jong Kim later in this book for ideas on the inclusion of systems science methodologies in teacher education programs.

5.4. Cultural implications.

We have tried to make the case that a curriculum organized and taught according to the principles of GSL would have greater cultural acceptance, especially in Asian countries. Is this indeed the case? This would be an important area for investigations among science educators and cultural thinkers of different countries.

5.5. Aesthetics in science curricula.

What can be the role of aesthetics in teaching science? We have suggested that art, music, literature related to the aesthetics inherent in the earth system and its processes can have a positive influence on student interest in science. We suggest using it only as a context for instruction, not taking the role of the art or literature teachers, but perhaps coordinating it with those teachers.

These are simply a few of the areas of research that would be opened up by the acceptance of the concept of GSL within the science education community.

6. CONCLUSION

Our objective in Global Science Literacy is to continue to teach students science and enroll them in the practice of scientific thinking and problem solving methodology. We differ from the science that seems to be practiced in most science classrooms around the world in that we argue for the inclusiveness of the 'systems sciences' approaches to investigative methodology in classrooms. We argue that science needs to focus on the grand ideas about how the Earth system and its environs in space function using them as the organizational framework for science courses rather than the traditional science disciplines. Science instruction should capitalize on the beauty inherent in our habitat by including the role of aesthetics in the teaching of science. Science instruction should emphasize the implications of science methodologies and practices in facilitating cross-cultural communication and understanding. Science based on GSL will emphasize those science understandings that shape our philosophical view that places us as a human species within the earth system, our home in space.

GSL deserves a careful look by science educators worldwide. We feel that it offers a fresh new vision for science education and for what quality programs can accomplish in classrooms around the world. It is a vision of inter-cultural cooperation and communication--a vision that offers to students and their teachers a fuller understanding and appreciation of their habitat, its history and future. With its inclusion of systems science methodology it offers an improved basis for developing critical thinking skills. It is also one, however, that can elicit greater interest in science among school graduates and thus enhance a nation's person power base in both science and technology.

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CHAPTER 2: EARTH AS A SYSTEM FROM THE PERSPECTIVE OF CHINESE CULTURE

Maan Jiang Broadstock, Formerly National Tainan Teachers College, TAIWAN, and Wittenberg University, USA

1. INTRODUCTION

The Chinese lived for more than five thousand years in a closed world with their country at the center. The name "China" in Chinese means the "Middle Kingdom"; the people of ancient China always thought that we were the center of the known world. The nations bordering China are home to peoples that migrated from China and share a similar culture. Over the centuries, the Chinese developed a culture that was influenced very little by western cultures and had no contact with other nations outside Asia. Western scientific thinking was largely formed during the Enlightenment when China was isolated from the West. This isolation created a unique culture with a different perception of nature and science and a difference in the way people thought in their daily lives. As Ogawa (1998) stated, "both science and science education as they exist in any culture are interpretations or constructions by the people of a given culture." He argues that science is a cultural "image", and this image produces a cultural and historical background linked to the way people think. Similarly, according to Slay (1999), "Chinese cultural values have affected the Chinese conceptualization of science and science education".

This chapter begins with a short discussion of Chinese philosophies and how they have influenced Chinese views of nature and science. A comparison of traditional Chinese thought and Western thought will be made, followed by a discussion of how traditional Chinese worldviews resulting from traditional philosophy fit into the concepts of Earth as a system and system science thinking. The chapter will conclude by applying the discussion to the appropriateness of Global Science Literacy to Chinese culture.

2. AN OVERVIEW OF CHINESE PHILOSOPHIES

The Chou dynasty (732-221 B.C.) marked the golden age of Chinese philosophy, and the complexity of the society cultivated many extraordinary philosophers in China. Among the various philosophies represented, two developed into distinct philosophical schools: Confucianism and Taoism. Even today, these remain the two most influential philosophical schools in Chinese history. Confucianism developed into the major official philosophy of the state bureaucracy during the Han dynasty. In the year 134 BC, Tung Chung-Shu, the prime minister of princes of the Han Dynasty, proposed to the emperor "to pay greatest esteem only to Confucianism and reject all other schools". Confucianism established a ruling position in ancient Chinese ideology. Although Taoism, never became an official philosophy in Chinese history, its mystical organic teaching nevertheless attracted many followers and has deeply influenced Chinese thought.

Confucianism derives its name from Confucius, who was a philosopher, thinker, educator, statesman, and the most highly respected teacher in Chinese history. The fundamentals of his teachings center around the unity of benevolence (li) and propriety (ren). Confucianism is the philosophy of society and man. It established ideological rules based upon common sense and practical knowledge for people to promote the cultivation of an individual's virtue. Confucianism provided Chinese society with a system of education and with strict conventions of social etiquette. "One of its main purposes was to form an ethical basis for the traditional Chinese family system with its complex structure and its rituals of ancestor worship" (Capra, 1991). Therefore, the normal goodness of human beings is the key to happiness (Koller, 1985, p284).

Taoism, in contrast, found the rules of happiness for human life not within humanity but within nature. It stresses the harmony and perfection of nature and is concerned primarily with the observation of nature and the discovery of its Way, or Tao. The main idea in Taoism is to lead humans to a unity with the universe by illuminating its Tao. The word Tao refers to the source and principle of the functioning of whatever exists. When humans follow the Tao of the universe and achieve oneness with this Tao, human beings will realize their nature, and peace and harmony will reign (Koller, 1985, p284-5). "Human happiness, according to the Taoists, is achieved when one follows the natural order, acting spontaneously and trusting one's intuitive knowledge (Capra, 1991)".

The originator of Taoism was Lao Tzu ("old master"), who is the author of *Tao Te Ching*, or the *Book of Virtue*. Differing from Confucian thought, Lao Tzu believed that efforts to develop and regulate the desires and emotions seemed artificial, tending to interfere with the harmony of nature. In chapter twenty-five of *Tao Te Ching*, Lao-Tzu expressed his ideas about Tao:

> There was something undefined and yet complete in itself,
> Born before Heaven and Earth.
> Silent and boundless,
> Standing alone without change,
> Yet pervading all without fail,
> it may be regarded as the Mother of the world.
> I do not know its name;
> I style it "Tao";
> ....
> Man follows the ways of the Earth.
> The Earth follows the ways of Heaven,
> Heaven follows the ways of Tao,
> Tao follows its own ways.
> (Translated by John, C. H. Wu, 1989)

His famous follower Chuang Tzu supported all things in their natural state and allowed them to transform spontaneously. In this way no action is needed, no regulations are required, and yet everything is done and all things are regulated. The principles that regulate human beings are the principles that regulate nature. For Taoism, "Life is lived well only when people are completely in tune with the whole universe and their actions are the action of the universe following through them.

(Koller, 1985). Taoism is naturalistic and individualistic. And because of its acceptance of nature and emphasis on transformation and process, Needham (1975) thought Taoism was the most influential philosophy in Chinese science.

Later in the Sung dynasty (AD 960-1279), a major philosophical movement, known in modern times as Neo-Confucianism, had developed, represented by Cho Tun-I, Cheng I, the Cheng Hao brothers, and Chu Hsi. Neo-Confucianism represents a harmonizing of the underlying principles of Confucianism, also borrowing from Taoism and Buddhism. As Cheng Yi said, "The principle in the world is one. Although there are many roads in the world, the destination is the same, and although there are a hundred deliberations, the result is one. Although things involve many manifestations and events go through infinite variation, when they are united by the one, there cannot be any contradiction." (Chan, 1963). Neo-Confucianism regarded the human being as a mirror image of the universe; each constructed according to the same proportions and sympathetically attuned to the other with a kind of cosmic resonance. The union between the universe and human is conceived as a conscious and animate continuum, as a sharing of life and experience that makes for order and harmony (Ching, 2000). This idea of "oneness of the heavenly and the human" (tien jen ho ye) has strongly influenced Chinese thinking.

Taoism and Confucianism share the distinction of being the philosophical grounding forces of Chinese culture. Some people think these two trends of thought represent opposite poles in Chinese philosophy, with Taoism representing the yin and Confucianism the yang of Chinese thought. Neo-Confucianism found perfection in the harmony of these two opposing principles. Confucianism emphasized the cultivation of the Way of Human Morality and the development of humanity by cultivating human-heartedness and social virtues. On the other hand, Taoism is primarily concerned with helping us to accommodate the Way of Humanity to the Way of Nature, to become one with the inner way of the universe. (Fu, 1997; Koller, 1985). Although many in the West tend to think that the two schools are ideological rivals, in China they were always seen as poles of one and the same human nature, and thus as complementary. "For more than two thousand years the traditional Chinese have managed to perform a delicate balancing act that allows them to be simultaneously Confucian and Taoist as appropriate to changing situations" (Fu, 1997). Just as Fang (1980) wrote in his book, *The Chinese View of Life and Creativity in Man and Nature*, he shows how Confucianism and Taoism complement and enrich each other. The Chinese view humanity and nature as a unified whole. Chinese philosophy is a way of discovering and clarifying the underlying unity of existence, with the aim of incorporating this wholeness into every aspect of life.

3.THE CHINESE VIEW OF NATURE

Cheng Chung-Ying (1997) discussed the origins of Chinese philosophy and pointed out that "for Chinese philosophers, the experience of changes in the world, in the seasons and in one's life is not a reason for getting away from changes or for denying their ultimate reality. On the contrary, these experiences lend Chinese

thinkers insight into the true nature of things and human self: there is opportunity for development, transformation, interaction and integration in nature and in the human self. This also suggests to them the organic wholeness of the world in which the changing and the unchanging, the objective and the subjective, merge and form a continuum because of the pervasiveness of change. To the ancient Chinese, this way of understanding reality is naturally simple and authentic, as evidenced by the experience of changes alone."

Both Confucianism and Taoism paid great respect to the thought of *I-Ching*, or *The Book of Changes*, and took inspiration from this book. *I-Ching* is one of the six Confucian Classics and is considered one of the greatest influential books in Chinese history. "In *I-Ching*, the experience of changes in nature by the ancient Chinese becomes consciously organized and articulated into a system of thinking about and describing reality. This organization and articulation not only provides a cosmological picture of the world in which man can find his proper place and proper role, but develops a way of thinking towards integrating the world and the self, generating meanings from facts and determining values from understanding" (Cheng, 1997, p503). *I-Ching* is based on yin-yang thought. The hexagrams of this book are often made to correspond with various systems, including astronomical and calendar units or generate classifications. The theories of The Great Ultimate (Tai-Chi), yin-yang, and the five elements (metal, wood, water, fire, earth) in *I-Ching* gave conceptual order to the traditional Chinese worldview. The Great Ultimate (Tai-Chi) signifies a totality of things, names nature as a whole, and presents a set of yin-yang relationships as the phenomenally most outstanding constituent forces and processes of nature. Therefore, the Chinese believe that everything is based on yin and yang, which defines a unity and a totality. In the process of yin-yang transformation from the stable, the hidden, the possible to the dynamic, people can experience the complementarities of opposites and the potentiality of progressive return and reversion, such as the change of the day and night and the seasons (Cheng, 1997). According to Needham (1975), "The Yin and Yang, and the Five Elements, never lent themselves to reductionism because they were always inextricably together in the continuum, and in the organic phantasms which came and went within it; never separated out, isolated or purified, even in theory."

According to Lao-Tse, nature is produced and governed in balance by universal laws, and the laws operate behind everything in heaven and earth; that he called Tao. The more man interferes with nature, the further harmony retreats into the distance. The more we force, the more trouble will result. To Lao-Tse, the world was not a setter of traps but a teacher of valuable lessons. Its lessons need to be learned, just as its laws need to be followed; then all will be well (Hoff, 1982). Therefore, for Chinese, the universe is the whole that is governed by Tao. This universe is constantly changing, and it cannot be separated apart and cannot be differentiated. Doing nothing but following nature and following the Tao is the basic concept for Taoism and is also a common philosophy among Chinese.

Therefore, the Chinese attitude toward nature can be summarized into three aspects: wholeness, organic, and process (Shen, 2000). First, all things in the universe are whole. Taoism holds that the Tao and universe are one and cannot be separated. As Chuang Tzu's said, "I was born with Heaven and Earth, all the

creatures and I are the whole". The concept of "oneness of the heavenly and the human" in Confucianism emphasizes that human behaviors are in the universe and should harmonically fit into the universe. Wang Yang-Min said, "The great man is the one uniting with the heaven, earth, and all things". Second, because of the wholeness, everything is connected together, interacting with each other and affecting one another. Things cannot be seen as isolated events or as existing independently. Wealth, astronomy, geography, wildlife, and humans are all linked together and affect each other. The Chinese view of nature can be seen as system with all its subsystems interacting and working together as a single organic system. Third, Chinese philosophy does not view nature as a collection of objects but as a continuous and endless process. According to *I-Ching*, "Yin generates yang, yang generates yin, and then yin again generates yang; the universe is a process in an infinite circulation." For Chinese, nature is a dynamic, continuous, and interrelated system. Although the various schools of Chinese philosophy differ in many details, they all emphasize the basic unity of the universe as the central feature of their teachings. The highest aim for their followers is to become aware of the unity and mutual interrelation of all things, to transcend the notion of an isolated individual self and to identify themselves with the ultimate reality. (Needham, 1975)

Traditional Chinese philosophy not only affects Chinese thinking about nature. It is also the foundation of the way Chinese deal with daily life. It guides family structure, relationships, business, painting, literature, and policy. For example, Chinese philosophy strongly influences the methods behind traditional Chinese medicine. Chinese medicine treats the whole person, or the whole body system, rather than the patient's isolated parts, and it treats patients in relation to their emotional aspect and physical environment. Chinese doctors believe that the way to heal the patient is to restore the balance between yin and yang in their patient's body. The traditional perspective of nature also influences Chinese thinking in science. Broadstock (1993, 1997) conducted a series of studies in understanding children ideas about the Earth system in Taiwan. The results showed that some elementary students expressed that nature is part of life that nature provides all the good for humanity, and that humans should live in harmony with nature. The results also showed that instead of believing that God made everything, as Christians believe, some young students did not believe that a single God directs the cosmos or created the universe. They expressed that everything has a spirit and collaborates with humans under the "order of Heaven". The order of Heaven they referred to is the "the cosmic order", which is similar to the Tao, or order of nature.

4.BETWEEN EAST AND WEST

Many studies have investigated the differences between Eastern and Western philosophies and how these different views have affected the development of science in these two cultures. In the West, there has been a tradition of analytical and causal thinking; westerners attempt to isolate elements and think in a scheme of cause and effect. The mechanical worldview lends itself to this kind of reductive thinking. In contrast to the mechanistic Western view, Joseph Needham (1975) sees the Chinese view of the world as "organic". In Chinese thought, all things and

events perceived by the senses are interrelated, connected, and are but different aspects or manifestations of the same ultimate reality. Western thought tends to divide the perceived world into individual and separate things, and people experience themselves as isolated egos in this world. In the Chinese view, the division of nature into separate objects is not fundamental, and any such objects have a fluid and ever-changing character. This worldview is therefore intrinsically dynamic and contains time and change as essential features. Needham (1993), as an organic philosopher, claims, "modern science fits organism better than mechanism." While westerners see cause and effect in discrete phenomena, the Chinese perceive a nexus of situations. While time and space are treated as abstract parameters in the West, the Chinese regard them as multiplication of phenomena. Things to be grasped in terms of impact in the West are comprehended as resonance by the Chinese, and hence the latter can conceive action-at-distance more easily. Capra (1991) in his book, *The Tao of Physics*, compared Eastern and Western philosophy and scientific thought. He said that "the Eastern thought and more generally mystical thought provide a consistent and relevant philosophical background to the theories of contemporary science, a conception of the world in which scientific discoveries can be in perfect harmony with spiritual aims and religious beliefs. The two basic themes of this conception are the unity and interrelation of all phenomena and the intrinsically dynamic nature of the universe. The Eastern thought has come to see the world as a system of inseparable, interacting and ever-moving components with the observer being an integral part of this system."

6. A DIFFERENT WAY OF THINKING IN SCIENCE EDUCATION

For centuries, the Western scientific model, a reductive, mechanism type of science, has dominated the science community. Science is studied and taught as a collection of pieces, facts and methods, and science curricula are divided into different disciples, such as biology, chemistry, physics, and earth science. Recently efforts on cultural studies in science education research have developed a new trend in which science itself is regarded as a culture of the scientific community. (Ogawa, 1995). Considering the importance of cultures affected people's view of science. Western mechanical science is no longer to be the only and absolute view of science. Kuhn (1970) argued in his book, *The Structure Of Science Revolution*, that science is not a steady, cumulative acquisition of knowledge. Instead, science is "a series of peaceful interludes punctuated by intellectually revolution." He described the term "paradigm" as essentially a collection of beliefs by scientists or a set of agreements about how problems are to be understood. The fundamental theme of Kuhn's idea is that the mature science is developed in the successive transition from one paradigm to another through a process or revolution. Considering the differences in Eastern and Western cultures, many researchers were seeking the new paradigm in thinking of science.

Capra and Steindl-Rast (1991) suggested a new paradigm for science thinking. The first criterion for this new paradigm is a shift from the part to the whole. In the old paradigm, people believed that in any complex system the dynamics of the whole could be understood from the properties of the parts. In the

new paradigm, the relationship between the parts and the whole is reversed. We understand the properties of the parts only through the dynamics of the whole, and because of the dynamic interaction within the whole, there are no parts at all. The second criterion is a shift from structure to process. In the old paradigm, people thought that there were fundamental structures and then there were forces and mechanisms through which these interact, thus giving rise to processes. In the new paradigm, every structure is seen as a manifestation of an underlying process. The entire web of relationships is essentially dynamic. The third criterion is a shift from objective science to epistemic science. In the old paradigm, scientific descriptions were believed to be objective, that is, independent of the human observer and the process of knowledge. In the new paradigm, it is believed that epistemology, the understanding of the process of knowledge, has to be included explicitly in the description of natural phenomena.

Many science education researchers also shift their thinking toward these new paradigms, toward a whole, processing, interacting, and dynamic approach, such as the Global Science Literacy and Earth system education.

7. CHINESE THINKING AND GLOBAL SCIENCE LITERACY

Chinese philosophy provides a great foundation for learning science in a global perspective view. Global Science Literacy accommodates Chinese thinking of wholeness. The universe is a unity without boundary, and humanity is part of nature and follows nature in harmony. The ancient Chinese never treated science as solid knowledge existing independently of the human moral world. For them, science was the dynamic process of humans interacting with their cultures and societies. This global view of science and the nature of the universe fit conceptually into Chinese philosophy. Although science is now taught based on the Western system in Taiwan and China, the fundamental beliefs from ancient Chinese philosophy allow students to see science in a different perspective, from a Global Science Literacy approach.

Chinese thinking also naturally melds into the seven understandings of Earth System Education (Appendix A). In the first understanding, Earth is unique, a planet of rare beauty and great value. The Chinese have expressed the beauty and value of Earth in their literature and arts for thousands of years, appreciating the creativity of nature. As written in *The Book of Poetry* more than two thousand years ago, "Poetry is the heart of Heaven and Earth". Human creativity will only be obtained from the appreciation of the Earth and Heaven. Chuang Tzu also taught us that, "Heaven and Earth (the Way) have the greatest beauty but are quiet, seasons have their routine but do not argue, and everything has its rulers but does not speak out. The sage is the one to preserve the beauty of Heaven and Earth and to understand the rule of everything. Therefore, sages should do nothing but observe nature and follow nature." (*Chuang Tzu*, chapter entitled "Autumn Water"). In the second understanding, human activities, collective and individual, conscious and inadvertent, affect planet Earth. As discussed above, the ancient Chinese taught that humans are part of the universe, and that humans had been and always will be interacting with nature. For the Chinese, following nature but not trying to dominate

nature is the way to ensure human happiness. The third understanding is that development of scientific thinking and technology increases our ability to understand and utilize Earth and space. As Needham (1975) said, "For nearly two thousand years before the beginning of modern science, there were no people in the world who observed the changes in the heavens more persistently and recorded them with greater amplitude and accuracy than the Chinese." Ancient Chinese invented tools to observe the sky to more deeply understand nature and its processes. They also developed the lunar calendar to record the changes of nature and planned human activities accordingly.

The fourth to sixth understandings include the concepts of the earth system being composed of interacting subsystems of water, rock, ice, air, and life; that the planet Earth is more than 4 billion years old and its subsystems are continually evolving; and that the Earth is a small subsystem of a solar system within the vast and ancient universe. Chapter twenty-five of the *Tao-Te Ching* described well the Chinese ideas about human beings, the Earth, the Universe, their relationships and dynamic processes: "Humans follow the ways of the Earth. The Earth follows the ways of Heaven. Heaven follows the Tao. Tao follows its own ways." The Earth is the natural environment in which humans live, that includes biosphere, hydrosphere, geosphere, and atmosphere. Humans utilize the five elements (metal, wood, water, fire, and earth) in this natural environment and find a balance in using natural resources to live in harmony with nature. The Heaven referred to is nature and includes the entire universe and its rules, with the Earth being just a small part of it. The Chinese concept of Earth and Heaven is as in the *Tao-Te Ching*, chapter seven: "Heaven lasts long, and Earth abides. The reason for their durability is that they do not live for themselves, that is the way they can live so long." Thus the Earth follows the rules of the universe, and the universe follows the way of Tao. In Chinese thought, the Tao is the Way, the endless and continuous process of the whole universe. And Tao itself comes from nowhere but itself.

The last understanding is that there are many people with careers that involve the study of Earth's origin, processes, and evolution. Perhaps the Chinese philosophy of wholeness can bring a new view to this understanding. This holistic worldview shows that human beings, no matter their nationality, race, or gender, are part of nature. The only way we can live peacefully and happily is to work together cooperatively to understand Mother Nature and its processes, and to preserve the Earth upon which we depend.

8. REFORMATION OF TAIWANESE SCIENCE EDUCATION

For decades, Taiwan's education system and curricula have mainly followed the system in the United States. Elementary, middle school, and high school curricula are developed independently. Starting in seventh grade, science is taught as different subjects, such as biology, physics, chemistry, and earth science. A reformation of Taiwan's educational system was begun in 1997, and in 2001 the new national curriculum, the Nine-Year-Continuous-Curriculum, was applied to the elementary and junior high schools. The major difference of the new curriculum is that, unlike the traditional curricula that focused on the content knowledge of

disciplines, the new curriculum emphasizes students' daily experiences and helps students to understand interactions and relationships with other people, society, and the environment. This new curriculum combines elementary and junior high curricula into an integrated and continuous curriculum with both global and local perspectives. In this new curriculum, science is taught under the name of "nature and life technology". This science curriculum moves toward an Earth System approach, addressing understanding the components of the Earth and the interactions of its subsystems, environmental issues, and how technology affects our lives and the Earth (See Chapter 5 for a complete description).

Within the last few years, many universities in Taiwan have started to provide an "Earth System" course as a required course for science majors and as an elective for non-science majors. This is not a traditional Earth science course but a course introducing the Earth as a system. Many topics, such greenhouse effect, global warming, ozone depletion, and natural resource devastation, are discussed. In 2000, an experimental high school taught Earth Science using the Earth System-Earth Resources Integrated Instructional Module (ESERIM), a set of teaching materials based upon Earth System concepts. A study (Chang and Lai, 2001) examined the effects of this module on 119 eleventh graders' science learning. The results showed that students significantly improved their understanding of ESERIM, and overall, students and the teachers gave very positive evaluations toward this module and enjoyed the activities and environmental topics. The researchers suggested that implementing the Earth system theme has the potential to serve as a model for future development of integrated curriculum and instruction.

9. CONCLUSION

Chinese philosophy provides a foundation for the Chinese to understand the importance of the wholeness, organic, and process viewpoints of nature. It also helps us to appreciate the universe as a system with Earth as a subsystem. Everything inside this system interacts with and depends upon each other. Understanding nature, appreciating nature, and following nature is the basis of Chinese philosophy and can also be the theme of Earth system education. Under Taiwan's education reformation, the concepts of Global Science Literary and Earth as a system are well suited to the new integrated science curriculum.

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CHAPTER 3: INDIGENOUS KNOWLEDGE AND GLOBAL SCIENCE LITERACY: A PERSPECTIVE FROM NORTH AMERICA

Eric M. Riggs, San Diego State University, USA

1. INTRODUCTION

As educators work to adapt science curricula and approaches to scientific knowledge to fit the larger context of integrated Earth systems in the Global Science Literacy framework, it is important to consider that most science as presented today was developed in the context of Western (i.e. Euro-American) culture and may not automatically work within the more general learning environment presented by the wide diversity of global cultures. This is especially true when working with scientists, educators, and students from non-dominant cultures or colonized indigenous peoples in any region of the globe. The enormous diversity of culture represented on Earth often presents radically different world-views, epistemologies, and relationships with Nature, all of which often contrast strongly with the dominant culture in any given region.

As the science education reform efforts in any country or region are usually based within a dominant national culture, marginalized or minority cultures within the educational system covered by national or regional governments must also be explicitly addressed if all students are to participate fully in the Global Science Literacy (GSL) revolution in science education. Virtually every region of Earth, especially those regions that have undergone colonization and/or decolonization, has surviving indigenous, pre-colonial cultures. The term "indigenous" is a very imprecise and relative term, and is ill defined and controversial especially in light of the geological and archeological understanding of human evolution and dispersion around the globe. This term has been discussed in its own right in a substantial body of literature, the review of which is well beyond the scope of this work. In this chapter, we present the term focused in the context of the latest wave of European colonization over roughly the last half-millennium, such that colonized peoples all over the world are therefore indigenous if they were present on the landscape for a large number of centuries or millennia prior to colonization by "modern" European entities.

Indigenous peoples are often a minority component of the larger societies that now surround them, and world-views held by indigenous populations are not always coherent or immediately compatible with the values and norms of the dominant culture. This creates, at a finer scale, the same problem encountered by the larger, global movement of GSL. The goal and the challenge is inclusion of all cultural approaches to scientific knowledge without the compromise of either the integrity of the scientific process or the wisdom collected over thousands of years by pre-colonial cultures that is contained within surviving indigenous knowledge.

This chapter seeks to synthesize a general framework for understanding the structure of indigenous knowledge from literature on the subject, and to apply this to the findings of ongoing cooperative work with Native American communities in Southern California. Because of the history of this region, the present study is also involved with establishing methods to determine the amount and extent of geoscience-related indigenous knowledge remaining in these communities after successive waves of colonization. However, this historical situation is common around the globe, and we argue that this experience can be generalized into many other similar settings worldwide and is therefore of wide applicability. Finally, this chapter seeks to outline some of the major problems and opportunities in working with non-dominant knowledge systems in the context of GSL-based teaching and learning, to present examples of indigenous knowledge in practice in adult education, and to suggest avenues for future research directions in indigenous geoscience education.

At present there is a small but rapidly growing body of research and scholarship in the field of *indigenous knowledge*, within which exists a body of scientific knowledge that is sometimes referred to as *ethnoscience*. Workers from diverse backgrounds and schools of thought have contributed to this body of work and to the wide range of definitions and terms for these ideas, which we will draw from below to construct a synthesis that is useful in the context of science education. These researchers have brought the intellectual tools and perspectives of history, anthropology, linguistics, sociology, science, and science education to bear on the study of how scientific knowledge is locally conceptualized and practiced in the place-based, cultural context of indigenous populations. It is not within the scope of this chapter to summarize or attempt to draw on all of this literature, rather the purpose here is to help workers trying to implement an Earth systems approach to science education gain a basic understanding of the major functional and theoretical issues and opportunities embedded in work with indigenous peoples.

In most cases, conducting scientific research or carrying out teaching and learning research in an indigenous or Native context also requires that a great deal of attention be paid to the political and economic circumstances of a tribal group. Therefore, the perspectives from the fields of political science, sociology and law are fundamentally intertwined in the application of GSL concepts in Native communities. In general, one cannot (nor should not) ignore the implications of Earth and environmental science expertise (or the lack thereof) in the *realpolitik* of indigenous cultural and community survival, and the influence this has on the adaptation and adoption of Earth systems education for and by these communities. Before conducting any research and curriculum development work with indigenous groups, it is important that geoscience educators educate themselves first in the history and current struggles of the indigenous groups with whom they are working, to better understand the curricular needs of the community they wish to serve.

2. NEGOTIATING THE INTERACTION OF INDIGENOUS KNOWLEDGE AND ETHNOSCIENCE WITH MAINSTREAM SCIENCE

The first problems in addressing how to fit a GSL curriculum to indigenous needs and to incorporate indigenous knowledge into an Earth Systems Science context are to identify A) what is indigenous knowledge; B) to identify where (i.e. with whom) such knowledge resides in a community, and C) how and *if* indigenous knowledge is best and most appropriately combined with mainstream science. Once these basic definitions have been established and one has an understanding of the state of scientific knowledge and expertise in a Native community, then (and only then) can work proceed in the development of culturally inclusive, Earth system science curricula. This is also an interactive, collaborative process, which cannot proceed without the complete cooperation and trust of the community in question. The pace of curriculum development and implementation, and the bounds placed on any educational program which is ultimately developed, must be set by the community not by any external "expert". As will be discussed below in more detail, indigenous communities are often wary of outside scientists and their scientific expertise for a wide variety of historical and political reasons. Care must be taken to protect the best interests, the intellectual property, and the cultural autonomy of indigenous cultural groups.

3. THE CENTRAL PROBLEM: WHAT *IS* INDIGENOUS KNOWLEDGE?

Despite the rather extensive literature which addresses the collection, preservation, appropriate treatment, and legal protection of indigenous knowledge, there are few instances in this body of work where authors have defined what this knowledge is, and to establish how it differs from other forms of place-based, geographically situated scientific and social knowledge. This is not from a lack of effort, in fact ecological and social anthropologists as well as environmental, Earth, and ecological scientists have struggled with forming a working definition of indigenous knowledge and associated concepts for at least the last two decades. However, as of yet no clear consensus on a definition has emerged. Louise Grenier, begins her concise book on the topic (1998), with the definition of indigenous knowledge as,

> ...the unique, traditional, local knowledge existing within and developed around the specific conditions of women and men indigenous to a particular geographic area.

At a minimum, indigenous knowledge is defined as knowledge which emerges from and resides within pre-colonial (i.e. indigenous) peoples, to the best extent that that status may be determined, and which is almost always concerned with the balance of humans and human activities within the interwoven functions of the natural environment and natural surroundings. As such, most indigenous knowledge is very practical in nature, and most of the day-to-day work in the collection and integration of indigenous knowledge worldwide is associated with the establishment of sustainable agriculture and environmental management in settings

where pre-colonial peoples still retain land stewardship and usually where "western" scientific approaches to environmental resource management have failed.

One of the most useful, practical, and operational definitions of the subsets of indigenous knowledge is presented by the Iowa State University Center for Indigenous Knowledge for Agriculture and Rural Development (CIKARD, 2002), which divides indigenous knowledge into four distinct categories:

> [Indigenous Knowledge] concentrates on four areas: indigenous innovations, knowledge systems (such as taxonomies), decision-making systems (such as what crops to grow on certain soils), and organizations (such as farmers' groups).

Embedded within the pursuit of indigenous knowledge in a modern operational context (and a science education context) are problematic notions of "sustainable" and "subsistence", as there is an implicit assumption that indigenous knowledge usually leads to and flows from sustainable development (agriculture, environmental and Earth resources, etc.) and is fundamentally the product of subsistence cultures. Hunn (1999) agues that while indigenous knowledge systems (*traditional ecological knowledge* in his text) are fundamentally local in nature, indigenous knowledge is therefore not concerned with the generation or discovery of "universal" or global scientific relationships, which sets it apart from the common goals of "western" science. But, indigenous knowledge is unique and is intrinsically valuable and worth preserving wherever it is found because it is born of cultures whose very subsistence depended on that knowledge for many generations. It therefore makes sense to protect and encourage the implementation and practice of indigenous knowledge in those local settings and to use indigenous knowledge systems as the basis for scientific education in those communities.

Because of its intrinsic value and its characteristics of being interwoven with the culture and values of indigenous peoples, indigenous knowledge needs to be identified as such as distinguished from other knowledge systems which have been overlain or imposed on indigenous communities, or which have origins in surrounding settler communities. The reasoning for the establishment of this distinction is that non-indigenous knowledge originates from colonial cultures and nations, which rarely have any intention of sustainable economic or environmentally benign extraction of resources from a given colonized region. One then cannot automatically expect locally viable solutions to problems of sustainability from non-indigenous knowledge, although it may be true in some cases that long-settled colonists have worked out local knowledge, which does result in sustainable practices. Hunn (1999) further points out that other key features of indigenous knowledge are an interrelationship with cultural, religious, social and other value systems which guide the application of knowledge in management practices. This is a point that will be discussed at length below, and one which bears important relevance in the construction of socially and culturally relevant science education for indigenous peoples.

Indigenous knowledge is not, then, simply a collection of scientific observations. We must find how this knowledge is linked epistemologically and socially to the community structure which gives rise to it. Relevant here also is the

distinction between indigenous knowledge, traditional knowledge, and local knowledge – all place- and culture-based knowledge systems which come into play in an ecological and educational framework. What follows is an attempt to encapsulate the relevant arguments and concepts in such as way as they may be useful to the development of Earth Systems education.

Kalland (2000) provides a useful theoretical framework for deconstructing indigenous knowledge, which we will adopt for the following discussion of the distinctions in the types of knowledge mentioned above. He proposes that indigenous knowledge is actually composed of three separate and independent types of knowledge, namely *empirical* knowledge, *paradigmatic* knowledge, and *institutional* knowledge. Empirical knowledge is defined as the observation and experience-based knowledge that results from long and direct experience working with natural systems. It is via empirical knowledge that the clearest connections and collaborations can be built between indigenous societies and scientists, and it is because of this that the preservation of indigenous knowledge is very important to scientific researchers. Put in other words, this is the "data set" of basic observations that a population holds and transmits.

Paradigmatic knowledge is, as the name suggests, the knowledge related to the interpretation and cultural construction of causal relationships, interrelations, and the meaning of these relationships within the empirical knowledge held within an indigenous knowledge system. These interpretations are embedded in and arise from culture and are shaped by the cosmology or world-view held by members of an indigenous culture. From a functional standpoint, indigenous paradigmatic knowledge can come into conflict with more traditional scientific world-views. For example, such a conflict might arise from analysis based on an underlying assumption of linear chains of causes and causation as opposed to those that are cyclical or interwoven. Similar conflicts might arise regarding other existing interpretive frameworks or standards for evidence. However, sometimes common practice within certain scientific disciplines offers valuable commonalities between the often more holistic viewpoint contained within the world-views of many indigenous people and a scientific framework. The Global Science Literacy – Earth System Science "world-view", which seeks to teach science organized around the inherent interactions and interconnections between empirically recognized sub-systems, is potentially quite coherent with many holistic indigenous cultural paradigms. Where in many cases a cultural barrier might be present because of the misfit between the world-view of reduction science and a student from a holistic indigenous culture, the GSL approach may provide a very useful bridge for facilitating the cultural border crossings reviewed in Aikenhead and Jegede (1999) and in recognizing the overlapping similarities in the bodies of knowledge commonly framed as "scientific" and "indigenous", as described in Agrawal (1995). Value systems and issues of appropriate relationships with nature and with scientific inquiry of natural systems are also embedded in paradigmatic knowledge, so connections to other aspects of cultural knowledge also come into play here. These might include religion, philosophy, and traditional relationships with authority and social structure, and potentially also cognitive issues related to temporal and spatial

scales. In geoscience education this might manifest itself in student conceptualization of what constitutes a "long time" or a "large system".

Finally, institutional knowledge is described by Kalland (2000) as the characteristic way that empirical and paradigmatic knowledge are operationalized in the daily existence and behavior of a population. These are habits and norms of management of access to natural resources or empirical knowledge of the natural world, along with social structures related to the acquisition, interpretation, and application of both empirical and paradigmatic knowledge. Kalland points out that in most cases it is reasonable to assume that empirical, paradigmatic, and institutional knowledge are internally consistent and mutually supported, there are examples from around the world where behavior is not necessarily obviously in concert with the paradigmatic ideals of a population (such as a culture which values balanced ecosystems inherently but ends up over-exploiting a resource because of institutional tradition). Often this can result from the introduction of external pressures as diverse as colonization to climate change, but the response of the population to these pressures is still governed by the institutional knowledge that regulates how the problem is solved and particularly who is given the authority to produce the solution. Institutional knowledge also can cause conflicts with externally mandated management practices or with externally introduced science education, especially if local practices and policies have not first been explored and checked for coherence with the externally developed practices and approaches.

There are other characteristics of indigenous knowledge that are worth adding to this brief sketch, mostly for caution and completeness for those who wish to pursue the documentation and application of indigenous knowledge in an GSL context. There are also a few key resources and organizations engaged in the systematic gathering and analysis of indigenous knowledge that are worth mentioning here. In her concise and practical guide to working with indigenous knowledge, Louise Grenier (1998) makes the point that indigenous knowledge is usually distributed widely and unevenly throughout indigenous cultures. Different subsets of empirical, paradigmatic, and institutional knowledge are often gender- or age-specific, or could be distributed by social status, role or profession.

Additionally, there is much knowledge that is distributed by individual factors such as skill, interest, or curiosity. To assess the entirety of indigenous knowledge in a population and to tap into that store of knowledge to enhance science education or any other activity, one must first build trust within a community and learn to listen carefully to community concerns. It was our experience in Southern California that once key members of our partnering Native communities understood that the intention of our work was to improve tribally controlled education and resource management, we were put in touch with the appropriate people within the community. News of our work spread fast through local tribal communities, which has resulted in more doors opening and more cooperation than we had originally imagined. Through these connections we have also slowly come to understand something of the distribution and structure of the indigenous knowledge held by the community, as well as the social structure through which one can propose educational innovations, which will be addressed in more detail below. In all cases, great effort must be made to make sure that local

cultures are empowered and respected by the sharing of their indigenous knowledge, and to a large measure this involves no more advanced skills on the part of the outsider than the ability to listen patiently and well, without imposing any judgment or demands on what is shared. International guidelines have been established which provide protocols for recording and transmitting indigenous knowledge, procedures through which local communities can become equal partners in any educational or other research venture, and means by which the intellectual property rights of indigenous peoples can be ensured (e.g. Grenier, 1998; Nakashima, Prott, & Bridgewater, 2000; Nuffic, 2002). It is very important that all attempts and explorations of the bridges between indigenous knowledge and Earth systems education be governed by these guidelines and work in concert with international initiatives.

One of the reasons for the emphasis on the protection and respect of indigenous knowledge systems is also the fragility of indigenous knowledge, and the rate of disappearance of indigenous knowledge, which has taken place in recent centuries into the modern day. Much of indigenous knowledge depends on being communicated and understood in the language in which it was originally constructed (Hunn, 1999; Thomson, Scott, & Whipple, 2002). The Navajo language, for example, has a grammatical structure which conveys meaning and movement through verbs in more complex and subtle way then English (Locke, 1992). Ethnogeological work in a Navajo context (Semken & Morgan, 1997) of show that this linguistic structure may provide Navajo students with a culturally-derived advantage in understanding Earth systems, as the interactions and processes are more central than the objects acted up on in the systems. Similar differences in mathematical and geometrical thinking related to this cultural and linguistic difference have also been documented (Giamati & Weiland, 1997). There is intrinsic value in the preservation of this diversity of thought and thinking skills, and there is often economic value in indigenous knowledge, as has been shown by the success of pharmaceutical advances rooted in indigenous ethnobotanical knowledge. But unfortunately languages are very fragile under the influences of colonization or globalization, largely because they are fundamentally local in nature and scope (Hunn, 1999). As a result, the languages and indigenous knowledge intertwined with them are rapidly disappearing (Lord, 1996; Thomson et al., 2002) or are already extinct.

4. INDIGENOUS KNOWLEDGE OR JUST LOCAL COMMON SENSE?

While many authors on indigenous knowledge have drawn no distinction between indigenous knowledge and local knowledge, we propose that there is a useful difference in these knowledge sets if the goal is to bridge cultural barriers in science education by including indigenous knowledge. Often in colonized regions it is not always immediately obvious what fraction of indigenous knowledge still exists among the original inhabitants, and what of that knowledge is common with much of the settler population and is the product of a few generations of life experience in the same geographical region, which is to say, *local* or *situated* knowledge. In a long-colonized region, such as Southern California and elsewhere in the

southwestern quadrant of the current United States, it is also valid to question if the indigenous knowledge surviving in Native populations is substantially different from the local knowledge since acquired by settlers who have now lived on the land for perhaps ten or more generations, as in the case of the ecological knowledge of Spanish-Mexican populations in the upper Rio Grande region of New Mexico described by Peña (1999).

By interpreting indigenous knowledge as consisting of three distinct sub-types of empirical, paradigmatic, and institutional knowledge, one can distinguish how indigenous knowledge is distinct from and related to local knowledge and how they are related to one another. Indigenous and local knowledge may share much the same content with respect to empirical knowledge, but the major difference being that the recorded memory contained with indigenous cultures can extend over a much greater time span due to the length of time spent living a given location. This allows for the observation of much lower frequency natural phenomena and usually leads to a cultural sense of cyclicity in natural events and a greatly expanded sense of long time scales relative to the settler culture (e.g. Riggs & Riggs, 2002).

While there is an obvious connection between "western" scientific knowledge and the empirical knowledge contained within in indigenous knowledge, not all that is included is empirical. The paradigmatic knowledge in traditional knowledge is culturally based and forms the interpretive framework for the empirical knowledge. This framework can be based in religion or spirituality, and while it itself is not scientific *per se*, one cannot ignore the influence of culture and tradition on the arrangement and acquisition of empirical knowledge. This issue has been discussed in the geological literature (Huckleberry, 1999; Riggs & Marsh, 1998; Semken, 1999), as it is a point of great importance and controversy among scientists who may attempt to dismiss the importance of paradigmatic knowledge or conversely worry that paradigmatic knowledge may be mistaken for empirical knowledge as scientists explore indigenous Earth science knowledge.

In distinguishing local knowledge from traditional knowledge, the type and source of the paradigmatic knowledge then seems key. While both types of knowledge contain empirical knowledge, the paradigmatic knowledge contained in both knowledge systems should be distinct. Paradigmatic knowledge in indigenous knowledge should be associated strongly with the local indigenous culture, and should be intertwined with world-view, religion, language and other non-colonial aspects of indigenous life. Colonial paradigms and institutions are commonly imported along with settlers, and are usually quite distinct from the cultural perspectives of indigenous peoples. If knowledge is fundamentally intertwined with culture, then empirical knowledge of a region held by people with transplanted paradigmatic knowledge will result in a different institutional knowledge set, or some hybrid of indigenous and settler culture. All of this should provide a means for distinguishing indigenous from local knowledge if one is involved in an assessment of what indigenous knowledge remains or which knowledge system seems to be dominant in management decisions, etc. The relevance of this distinction will be discussed further below, as it directly influences educational and curricular decisions in locations where the extent of surviving indigenous knowledge is not clear, and where the educational avenues provided by local and indigenous knowledge may be

useful in reaching diverse populations or under-represented groups. It is also a distinction potentially useful in shaping the framework of Earth Systems science education (GSL) for these same populations.

It is important to acknowledge at this juncture that much of the framework presented above remains largely untested in the field in Southern California and elsewhere. While significant progress has been made in the identification of indigenous knowledge relevant to Earth science education in Native North American populations, especially with the Cree (Murray, 1997) and the Navajo (Semken & Morgan, 1997), the framework presented above has not been tested in these settings or used as a discriminant for sorting out knowledge systems currently in use in Southern California tribal communities. Hopefully this framework will serve to provide impetus for further research in this direction.

5. RESERVATION REALITIES AND EARTH SCIENCE EDUCATION

In parallel with the development of research and understanding of the nature and value of indigenous knowledge, has come the clear need for increasing the ethnic and cultural diversity of the geological and related Earth sciences (Marcus, 2002; Semken & Morgan, 1997; Zappo, 1998). This has been accompanied in the United States by support for these efforts by funding agencies that traditionally support geoscience research and graduate training, notably the National Science Foundation. This welcome attention to diversity issues from research scientists and funding agencies has led to increased support for geoscience education research into the nature and structure of cultural barriers to entry for traditionally under-represented groups.

Many ethnic and cultural groups are persistently under-represented in Earth science (Matthews & Smith, 1994 and references therein; Zappo, 1998), with the situation being only marginally better in environmental and agricultural sciences (NSF, 1999; 2000). In the North American context, Native Americans and First Nations peoples in general, as an under-represented group, are of particular concern for Earth and environmental science educators because of the large land base managed by tribal authorities coupled with the simultaneous lack of professional scientific expertise within reservation communities themselves (Bevier, Evenchick, Thompson, & Wyss, 1997; Riggs & Marsh, 1998; Riggs & Semken, 2001). Despite the great richness of Native empirical knowledge related to environmental stewardship and the Earth (e.g. Martinez, 1996; Suzuki & Knudtson, 1992), the lack of on-reservation, scientific expertise often results in tribal communities being forced to rely on outside expertise when dealing with the technical issues, as the staff of many tribal water and environmental offices often does not have the scientific background to read and interpret technical reports, environmental impact statements, etc.

Even when the language of empirical knowledge can be translated, the institutional context of land use and resource management from a dominant culture perspective often does not mesh well with the institutional knowledge structure of a Native community. While non-native geoscience professionals hired by tribes are usually thorough in their work and sincere in their desire to help tribes make good

resource decisions, the lack of a shared cultural perspective places both the external consultants and tribes at a disadvantage in achieving clear and open communication. The cultural mismatch is often related to gaps in the value systems (paradigmatic knowledge) related to development, land use, and environmental stewardship. Practical issues also commonly arise regarding the sensitive and proprietary nature of the data collected by non-Native consultants and scientists on tribal land. Many Native American communities have also experienced adversarial relationships in prior dealings with professional Earth and environmental scientists, because there is a clear historical link between the work done by these professionals, the reporting of collected data to either the scientific community or to corporate and governmental entities, and to the ultimate dispossession of Native people of these natural resources (Churchill & LaDuke, 1992; Deloria, 1995; Guerrero, 1992; Karr, 2000). Naturally this history sometimes complicates the building of cooperative relationships between scientists, educators and tribes.

6. GENERAL ISSUES IN CROSS-CULTURAL SCIENCE EDUCATION FOR INDIGENOUS PEOPLES

Compounding the existing difficulties in empirical and institutional aspects of indigenous knowledge discussed above, science education in Native communities is made harder still by the fact that teaching and research styles common to much of science are not automatically compatible with much of the paradigmatic and institutional knowledge within indigenous knowledge. This is one of the key reasons cited for the under-representation of Native Americans in the sciences in general (Nelson-Barber & Estrin, 1995). There is often a specific conflict with the perception of the role of the scientist as a controller, manipulator, or exploiter of the natural world (Murray, 1997; Riggs, 1998). All of these reasons can set up internal conflicts for indigenous people (and other minority cultural groups as well) in science classrooms and with scientific work in general as they struggle with "cultural border crossings" (Aikenhead, 1996; 1997), which are the transitions between the daily world-view and life-ways of indigenous peoples and the culture and norms of science. The nature and severity of these border crossings are a function of both the students themselves (Aikenhead, 2001b; Costa, 1995) and the curricula and teachers they encounter. The wide range of cognitive and behavioral strategies employed by indigenous and other minority students to negotiate and mitigate the relative level of assimilation or acculturation they experience in learning science has been studied in detail by Aikenhead and Jegede (1999). Classroom pedagogy and discourse is also strongly shaped by the underlying epistemological values of the instructors and students (Yerrick, Pedersen, & Arnason, 1998), and classroom assessments must also be adjusted to reflect the cultural influences on students' construction and valuation of scientific knowledge (Solano-Flores & Nelson-Barber, 2001).

These differences in ways of knowing among Native American and other indigenous students can lead to both significant problems and opportunities in the approach to community and classroom science education, especially in the context of Earth systems science. Many of the problems, as described above, relate to the

history and politics of the Earth sciences and indigenous peoples. However, the opportunities for combining traditional ways of knowing and scientific knowledge into a continuous pedagogical approach for students are numerous in the Earth sciences and we maintain that these opportunities and potential benefits are sufficient to outweigh the problems. Warren and co-authors (2001) show that successful linkages can be made between science and the everyday world of minority students provided that science is carefully presented in the classroom as just another portion of students' everyday lives rather than some foreign body of thought and knowledge that is fundamentally separate. They argue that the key is that science must be shown to be congruent with common ways of logical thinking that students recognize from within their own cultures, using everyday experience to illuminate and provide context for scientific instruction.

We will illustrate below that the Earth system science provides many opportunities for providing linkages between the everyday lives of students and the world of science, and that the key to finding the right connections between the daily lives of indigenous communities and science is in identifying and understanding the indigenous Earth science knowledge that still lives on within tribal communities. Understanding the nature and structure of indigenous knowledge, along with the history and current political and economic situation of a tribal population, leads to an understanding of which elements of the local environment can provide the best connections to the geosciences, and points the way toward content areas which will spark the most interest and be of the most value to the communities with whom we work.

7. EARTH SCIENCE EDUCATION AND THE EXPLORATION OF ETHNOGEOSCIENCE

There have been a number of positive developments in North America in bridging the gaps between indigenous groups and scientists and educators within the dominant culture in the Earth and environmental sciences, especially in the approach taken in Native communities to Earth and environmental science education. A significant number of geoscience education research and outreach projects in recent years have worked at the interface of indigenous and scientific knowledge to find common ground in empirical knowledge and to find ways for indigenous communities to most effectively manage the merging of indigenous and scientific knowledge. This has resulted in a wide variety of regionally adapted Earth and environmental science classroom curricula and field courses for Native Americans and First Nations people. Semken and Morgan (1997), for example, working in the Navajo nation have successfully developed an integrated Earth science curriculum for Diné College, the tribal college of the Navajo nation, and for professional development of K-12 teachers on the Navajo reservation (Dubiel, Hasiotis, & Semken, 1997) which incorporates a Navajo framework for understanding nature and Navajo language into a learning structure where the major themes of Earth science are related directly to the natural processes embodied in a traditional Navajo understanding of the Earth. The curriculum also incorporates traditional pedagogy and traditional empirical Earth science knowledge where possible, all with the goal

of reducing the magnitude of the border crossings required by students. The work at Diné College is particularly advanced relative to other indigenous Earth science curriculum development projects largely because the mission of the college explicitly instructs faculty to build in traditional Navajo knowledge wherever possible and to strive to maintain the cultural integrity of the Navajo nation. Because of the large size of the Navajo nation and intact culture and language on the reservation, there is also little doubt as to what is and is not indigenous knowledge, giving science faculty a distinct advantage in identifying empirical knowledge which can be successfully built into science courses. The work at Diné College has served as a model and as inspiration, and similar projects at various stages of maturity and with differing goals and audiences now exist scattered throughout the United States and Canada (e.g. Bevier et al., 1997; Murray, 1997; Riggs & Riggs, 2002). The hallmark of such efforts is a focus on the particular needs, environment, experiences, and learning styles of local tribal groups.

8. THE INDIGENOUS EARTH SCIENCE PROJECT: A SOUTHERN CALIFORNIA EXAMPLE

Southern California Native Americans have not historically benefited from much Earth science curriculum adaptation work, largely because of the relatively geographically and culturally fragmented nature of the surviving Native population. Despite the fact that California has the largest Native population of any state in the United States, the individual tribal groups are relatively small (usually under 2000 residents, frequently under 200) and were historically located in relatively remote areas, although today recent suburban development has expanded outwards to near tribal lands. The small and scattered structure of tribal bands today is partially due to the consequences of colonization and the removal of tribes from arable land and the lack of firmly established reservation boundaries or ratified treaties when California gained statehood (Shipek, 1988). Much of this current distribution of peoples is also due to the fact that California natives tended traditionally to settle in extended family groups, often within geographically bounded regions, such as watersheds, valleys, desert basins, or mountainous areas (Bean, 1972).

As a result, the indigenous Earth and environmental science knowledge contained within the traditions of separated but culturally-related tribal groups is potentially extensive, as California Natives were not generally nomadic, but stayed in a relatively confined area and developed a deep familiarity with geologic, surficial, and environmental processes and features. The current indigenous cultural landscape of Southern California includes diverse reservation-based communities and multiple mixed-ethnicity urban groups and other major cultural groups, which do not currently have reservations but do have thriving communities. The Native landscape of Southern California, northern Mexico and western Arizona is amazingly diverse, with many language groups and Native cultural heritages represented.

Nearly half a millennium of European colonization has taken its toll on the integrity and coherence of Native cultural and language in this region, further complicating an already complex historical cultural landscape. The modern

challenges for the roughly 30 reservation-based communities in Southern California today (some reservations are unoccupied, so the definition of community is problematic) are related to the extensive population and development pressures in the region, specifically those related to water rights, environmental degradation, landfills, and mineral resource development (e.g. Karr, 2000). Adding to the problems, most tribal communities do not have their own full-size schools because of their small size. They therefore generally rely on the mainstream public school system, supplemented by small tribal learning centers that offer limited culturally specific programs. Tribes in this region are also interested in increasing their geoscientific literacy and education within their communities at all educational levels, allowing fruitful and ongoing collaborations with outside educators and scientists.

The Indigenous Earth Sciences Project (Riggs & Marsh, 1998) was founded in response to these needs, and with the explicit recognition of the role of the potential of indigenous knowledge among Southern California Native American groups concerning the Earth and the natural world. Furthermore, because of the active inquiry and field-based components which are common to Earth and environmental science education, the IESP was founded to explore the proposition that the geosciences should offer a more culturally compatible entry into science for Native American students, because of the fundamental similarities of teaching styles and settings common to the Earth sciences and learning styles common to many Native Americans. The project continues today through activities at a variety of educational levels in cooperation with the learning centers and tribal environmental offices on a few partnering reservations in the San Diego region. We are actively working to determine what of the potential indigenous knowledge remains intact and how to find how that can be incorporated to help raise the scientific expertise on reservations. To simplify the cultural environment in which we attempt to apply the framework described above for identifying indigenous knowledge, and to maximize the effect of the programs we do develop, most of our work has recently been concentrated within the Luiseño and Cupeño communities of the San Luis Rey river watershed in northern San Diego county. We have to date uncovered a few key elements of successful Earth and environmental science education in the local indigenous context, and have also begun to identify the working elements of surviving indigenous knowledge. These emerging discoveries and their educational potential are discussed below.

9. GEOSCIENCE EDUCATION AND INDIGENOUS KNOWLEDGE IN SOUTHERN CALIFORNIA

As one of the concluding sections of this chapter, we will employ the framework established for the deconstruction and analysis of indigenous knowledge to the experience accumulated to date working to improve Earth and environmental science education for Native Americans in Southern California. While this analysis is far from exhaustive and much of this work is still in progress, it is our hope that these small portions of indigenous knowledge which have been graciously shared with us by Native people will provide readers with more concrete examples of how

indigenous knowledge can be recognized and applied in an Earth science education context, and in the context of other research in science education. At the very least, these vignettes provide a direction for future research, for which there is a great need in this field in general.

Many of the early lessons learned in the first four years of the IESP came from the initial two conferences that launched the project. In those meetings with tribal representatives and Earth scientists from the U.S. Southwest, reported in Riggs and Riggs (2002), specific issues in indigenous geoscientific knowledge were explored. The largest cultural divergence for Native people from the Euro-American mainstream focused on general themes of time scales, spatial scales, and interconnections in Earth system processes. These same themes also emerged as common elements in those Earth systems science curricula that have been designed for Native Americans.

Native communities, as discussed above, tend to have a fundamentally longer time perspective on processes, which is reflected in the empirical and paradigmatic portions of their indigenous knowledge. An example of this was provided by a representative of the Morongo band of Cahuilla Indians, a reservation community located in the arid Coachella Valley of Southern California near the towns of Banning and Palm Springs. Geologically, the reservation is northeast of one of the strands of the San Andreas fault, and is built on a sloping alluvial fan constructed of sediment derived from the San Bernardino mountains which provides a good sand and gravel aquifer. Runoff from the mountains infiltrates into this alluvial aquifer and is a reliable source of high quality water for the reservation. The fault acts as a kind of underground dam for this high-quality water, keeping most of the supply under the reservation and preventing the water's escape into the larger Coachella Valley basin. The town of Banning lies on the other side of the fault from the reservation, and uses the ground water found in the main basin as a major water source. Because their withdrawals have exceeded the local recharge rates for this ground water basin, the town wanted to import relatively high salinity water from the Colorado River to replenish the underground reserves. The fault strand provides a low permeability barrier between Banning's and the tribe's aquifers, but low permeability does not mean impermeable, and there was bound to be some exchange of salinity over time between the imported water injected into the town's aquifer and the higher-quality water under tribal control. The Banning water authorities claimed that the exchange time would be long and would not impact the tribal water quality in the near term. For the town, a "long time" amounted to something on the order of 200 years. The tribe rejected this argument, and opposed the injection of Colorado River water because in their opinion 200 years was merely an instant of time, and not a long time at all. From the perspective of tribes who have lived in this natural landscape for at least 8,000 years and potentially tens of thousands of years, a few thousand years may have been viewed as a "long time", but not 200. This is a clear example of the culturally based paradigmatic differences in the knowledge held by both groups. In this case the paradigmatic portion of indigenous knowledge came to bear on a management decision, related fundamentally to an indigenous worldview and perhaps also to empirical knowledge of longer term, lower frequency events in the natural landscape. While both groups possessed empirical knowledge of water

flow and mixing between aquifers, the settler community's paradigm did not incorporate the same kind of long temporal view, and resulted in significantly different management decisions being made based on the same empirical data. Reservation communities and other tribal entities everywhere in North America must co-exist with the dominant settler culture, and the type of practical problem illustrated above is typical of what and tribal natural resources managers struggle with to maintain, protect, and grow tribal water systems, sewage systems, and other built infrastructure while preserving the natural environment and future resources of the tribe. Stories like those of the Morongo reservation are a key example of why it is important to work to find ways to combine scientific and indigenous knowledge to result in more sustainable management decisions.

Most of our recent work has been with the EPA-funded tribal water office on the La Jolla reservation in northern San Diego County. In conducting this work over roughly the last year, we have found that while much indigenous knowledge and certainly indigenous culture are still intact and are a part of people's everyday lives, the daily needs and problems of the tribe's environmental managers tend to center on the use of mainstream chemical, biological and geological science. However, indigenous management practices and knowledge of the physical and biological environment still come into play, and we are currently working to find ways to incorporate this to guide the education and ongoing water resources work done by the tribe. The La Jolla community of a few hundred Luiseño people is situated in a 8,500 acre mountainous and rural reservation in northern San Diego county. It is the home of the late Henry Rodriguez, an outspoken and effective tribal activist and Native environmental and resource rights champion. His long standing battle to preserve the water rights of all San Luis Rey watershed Native communities (described in Karr, 2000) helped foster a local awareness of the need for Native hydrologists and geologists on these many small reservations. Based on the success of a service learning project conducted between the tribal learning center and SDSU Geological Sciences, the La Jolla community approached the author and co-workers to see if we would be willing to start cooperative workshops for tribal environmental professionals in Earth and environmental science. To date we have now had six Friday afternoon workshops which have all focused on the geoscience content related to the rocks, hydrology, and environmental biology of the reservation as well topics related to slope stability, water system development, and other practical problems currently facing the tribe.

The indigenous Earth systems knowledge, which has been shared with us to date, involves springs and their relation to the small fractured bedrock aquifers and also riparian health as gauged by vegetation. The riparian vegetation indigenous knowledge is not well investigated by the author at this point, so it will not be addressed here, but it has been reported by indigenous people in the region (e.g. Cuero, 1968) and explored by anthropological workers.

However, the information on springs has emerged directly in our sessions at La Jolla. Some members of the tribe, at this point all men, have shared detailed knowledge of the location and characteristics of springs of varying sizes on the reservation, most of which are not mapped on the U.S. Geological Survey topographic maps which cover the reservation. In addition to the location of these

features, they are also aware of the times of year when these springs flow and roughly how much water can be expected to be available from them. This empirical knowledge could be either local or indigenous, but there is some suggestive evidence that this knowledge of springs is rooted in indigenous knowledge. The evidence is an oral tradition, which states that the location and characteristics of the springs change after large earthquakes. This is consistent with a geological interpretation of the origin of these springs at the intersection of joints and other fracture systems in the underlying plutonic igneous rock. Large earthquakes can cause subtle shifts in flow paths through fractured bedrock as large blocks of rock move in response to seismic shaking. The reservation abuts a major strand of the Elsinore fault as it traverses the Peninsular Ranges, and large earthquakes are known to have happened along this portion of the fault. The suggestion that the source of this knowledge is indigenous in origin is related to the fact that there have not been any recent (since 1812) large earthquakes on the portion of the fault that runs through the reservation, at least not any that have been well located (SCEC, 2002). The fault is noteworthy for being one of the quietest in Southern California, and has been estimated to have an average recurrence interval for large earthquakes of roughly 250 years. While the Euro-American colonial record is not long enough to have captured evidence of large earthquakes which may have affected springs, the lack of common large events is certainly suggestive (but not conclusive) that knowledge of spring shifts associated with large earthquakes is knowledge recorded by the indigenous societies living in this region and is not simply local knowledge. In this case, the determination of local vs. indigenous knowledge is made by the time scale inherent in the empirical knowledge, consistent with the discussion in the first sections of this paper. The fact that primarily men have knowledge of springs while women hold knowledge related to riparian vegetation is also consistent with indigenous institutional knowledge, further supporting the identification of these bodies of knowledge as indigenous in origin.

10. INCORPORATING INDIGENOUS EARTH SYSTEMS KNOWLEDGE INTO EARTH SCIENCE EDUCATION

Our work with indigenous peoples in Southern California is in its infancy, but gradually more indigenous knowledge will be identified. The challenge that follows is then to incorporate this knowledge into locally relevant and culturally accessible curricula for Native American learners of all ages. We have adopted the general approach presented in Aikenhead (2001a), in that all of the adult education sessions and earlier sessions with children have focused on themes related to daily reservation life and central themes in local indigenous culture, all of which has been constructed in collaboration with tribal educators.

From a teaching and learning standpoint, the most effective feature of our sessions to date on the La Jolla reservation has been the emphasis on fieldwork and field teaching. Upon the suggestion of community members during our early sessions with children and our first session with tribal environmental professionals, we moved our geological and environmental science sessions outdoors, to sites of interest to the tribe and where real tribal needs encountered the natural environment.

Science education in the field is normally beset with numerous barriers to learning, centered on the novelty of the environment. Orion (1993) and Orion and Hofstein (1994) develop a model of "Novelty Space", consisting of psychological, geographic, and cognitive factors. Their work with high school students learning geology in the field shows that the most effective learning in a outdoor teaching environment happens when students are psychologically prepared for field work (they know the physical conditions, length of stay, etc.), are geographically prepared (i.e. they understand where they are relative to other places in their world), and are cognitively prepared, in that they have some prior knowledge on which they can draw to understand the material they are presented in the field environment. If all of these factors are met, then students are said to have enjoyed "Optimal Concrete" preparation and learning is maximized.

From this perspective, the Native American learners in our program are all at the "Optimal Concrete" preparation stage and Orion and Hofstein (1994), in that most of the elements of Novelty Space, especially psychological and geographic factors have already been addressed by the time any content instruction begins in the field. All new geological content then adds to any existing indigenous and local (meaning both sets of empirical and paradigmatic knowledge) held by participants, and all knowledge is also then immediately contextualized into a familiar environment. In the Earth sciences, fieldwork is also most often cooperative in nature, and this has been true of our outdoor instruction. Fieldwork is also generally teacher-structured, but has major components of student-structured instruction as the details of which data is collected and how it is recorded and interpreted is usually left to the students. All of these factors are completely consistent with recent findings in learning styles research with Native American students (Aragon, 2002), and suggests as a recommendation for practice that most Earth science education with indigenous peoples should be conducted in the outdoor teaching environment. The learning gains in this setting are likely to be much greater than if restricted to the classroom, and this is supported by our small qualitative data set at this point. The systematic, quantitative measurement of these learning gains has yet to be conducted and is a rich avenue for future research.

By way of recommendations and conclusions, we reiterate that indigenous knowledge can be located only with the full cooperation of Native people, and differentiated from local knowledge by the framework presented here. It can be most effectively combined with instructional innovations shown to be effective to make curricula that are relevant and useful to indigenous learners. One the most powerful teaching strategies in an indigenous context is the use of the local field environment, especially on lands which have been occupied and managed by indigenous people for generations. In all the projects in North America to date, this has been a common theme, and elsewhere in the world with other indigenous populations, this is also the case. The field is one of the easiest teaching environments in which to make connections between scientific and indigenous knowledge, and it is also one of the best places to explore the interaction of Earth systems. While the effectiveness of a Earth Systems Science approach is not yet fully understood in an indigenous context, fieldwork and other experience-based teaching styles are likely to hold the greatest potential for the enhancement of

diversity in the geosciences as well as the greatest potential for bringing Earth and environmental science expertise to indigenous populations worldwide.

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CHAPTER 4: THE OUTDOOR AS A CENTRAL LEARNING ENVIRONMENT IN THE GLOBAL SCIENCE LITERACY FRAMEWORK: FROM THEORY TO PRACTICE

Nir Orion, Weizmann Institute of Science, ISRAEL

1. INTRODUCTION

The Global Science Literacy approach places the concrete environment – the earth systems – in the heart of the learning process. Therefore there is no doubt that any GSL curriculum should emphasize the use of the outdoor as a central learning environment. However, although each year, many classes visit outdoor settings (e.g. science museums, zoos, natural history exhibits, and nature parks), the use of the outdoor learning environment within the formal education system has not fulfilled its educational potential. There is no doubt that logistic limitations, which exist in the school system and lack of adequate teaching/learning materials impact on the teachers' abilities to use the outdoor learning environment. However, the key factor for limiting the use of this learning environment is the ability and the willingness of science teachers to deal with this learning environment. Most teachers are unfamiliar with the philosophy, organization and didactics of field trips and in general they perceive out-of-school visits as an enrichment or/and a social event with vague or limited learning goals (Bringham and Robinson, 1992; Gottfried, 1980; Griffin and Symington, 1997; Orion and Hofstein, 1994; Pontin, 1995).

However, it might be a big mistake to look at the teachers as the main reason for the poor educational outcomes of the out-of-school learning environment. In fact, teachers' lack of understanding of the complexity and educational value of the outdoor environment are due to the followings two reasons: (a) the failure of the science education research community to present clear and coherent answers for the most basic questions, such as why, when, where and how. And (b) the intensive activity of external (informal) education bodies within the formal system that led teachers to perceive the out-of-school as an external learning environment, which is not an integral part of their formal teaching duties.

For example, Thomas and O'Donoghue (1990) noted that one of the primary recommendations of the International Symposium on Fieldwork in the Sciences was "...to develop appropriate pedagogic techniques based on knowledge of how children learn..." (p. 201). It would seem that this neglected state of outdoor education reflects our limited knowledge and understanding of the outdoor as an effective learning environment. For example, McClafferty and Rennie (1992) reviewed 39 studies, published between 1974-1992. These studies neither investigated factors that influence students' ability to learn in an outdoor setting, nor focused on the implementation of field trips as an integral part of the science curriculum. Moreover, most of those studies were conducted in an informal learning context. A more recent example is found in the journal ***Science Education*** (volume 81, issue 6) that was published in 1997 and dedicated to the out-of-school learning. Here again, only a few of the 11 articles included in that special issue dealt with the

role of the outdoor learning environment within the formal learning setting and the role of the science teacher in this teaching/learning process.

It should be noted that this review is not intended to be critical. From their point of view these studies have a significant impact on science museums and other external settings. However, they have only limited influence in convincing curriculum developers and science teachers to integrate the outdoor learning environment as an integral component of the classroom learning process. It is suggested that only a systemic, holistic approach might lead to this conceptual change. In order to implement this change teachers should understand the following elements of outdoor learning:

(1) What is an outdoor learning event?
(2) Why go outdoors? (What is the role of the outdoor learning environment in the learning process?)
(3) What is (are) the preferred learning style(s) for the outdoor learning environment?
(4) How should an outdoor learning event be implemented within the learning process?
(5) How can we encourage teachers to use the outdoor learning environment?

In effect, these questions relate to research, development and implementation. Thus, in order to improve the planning and execution of purposeful field trips, research should focus on better understanding of the outdoors as a learning environment. Such was the focus of the author's research in the last ten years (Orion, 1989; Orion, 1993; Orion, 1994; Orion and Hofstein, 1991; Orion and Hofstein, 1994; Orion and Rosenfeld, 1996; Kempa and Orion, 1996; Orion, Hofstein, Tamir and Giddings, 1997). This research together with other important studies (to be mentioned later) are the basis for this paper, whose purpose is to present a practical model for planning and implementing an outdoor learning activity as an integral part of the curriculum.

2. WHAT IS AN OUTDOOR LEARNING EVENT?

A major impediment to progress in the area of out-of-school science trips results from generalizing the outdoor learning environment. Such generalization fails to take into account the bewildering diversity of outdoor settings. Therefore, without a common conceptual framework to distinguish between the many different types of field trips on a systematic basis, the accumulated efforts of researchers, program developers and program implementers alike are in danger of being confounded.

The research literature makes it clear that while science field trips encompass a tremendous variety of different learning experiences, researchers often fail to differentiate between these experiences. For example, summaries of science field trip studies by Koren and Baker (1979) and Mason (1980) lump together outdoor visits together with visits to indoor environments such as museums and factories. In another summary, Sorentino and Bell (1970) defines the term "field trip" even more loosely, i.e., as any organized visit outside of the class to achieve an educational goal. Missing in these three summaries is any attempt to distinguish the important differences between different field trips.

Common sense dictates that distinctions need to be made between different field trip variables, since such differences may well be responsible for different answers to the basic questions posed above. To illustrate this claim, consider the physical factors, which differentiate between the different out-of-school learning environments. These factors might include (a) accessibility to desired resources (low to high), (b) human influence (totally natural surroundings to man-made structures), and (c) weather (degree of rain, sun, humidity and temperature). Consider how each of these factors might differentially affect different out-of-school environments:

(a) Distractions - The term "distractions" can be understood as stimuli, which deflect the learner's attention away from the learning task. In general, there are fewer distractions to a learner in a natural setting than in an indoor setting. For example, in a museum there is a relatively higher density of things to see and these may distract the visitor's attention.

(b) Accessibility to desired resources - Each field trip is connected with a number of desired learning stimuli or resources. In indoor environments, such as museums, the accessibility to these desired resources is high. However, this is not usually the case in natural surroundings; for example, one cannot insure that a particular animal will be observed at a specific time and a specific location.

(c) Weather - The surroundings of each trip can be characterized by such factors as the presence and abundance of rain, sun, humidity and temperature. Clearly, weather is a much more critical factor for field trips in the natural environment than for trips to indoor environments, such as museums.

The outdoor learning environments: The above three parameters enable us to differentiate the physical learning environment into three different types:

- The natural (outdoor) environment. Examples: wilderness and nature areas.
- The semi-natural (indoor/outdoor) environment. Examples: zoos, outdoor science centers, urban surroundings.
- The man-made (indoor) environment. Examples: Natural history museums, science/technology centers and industrial sites.

Figure 1 illustrates only a rudimentary framework since each of the three sub-environments presented above should be differentiated at a more detailed level. For example, although museum and an industrial site are both a man-made (indoor) environments there is a significant difference between them. The same distinctions can be made between a zoo and an urban setting. Moreover, there are major differences among different types of museums and visiting centers. Thus, a description of a physical outdoor environment should also include information such as the learning facilities, the type of interaction with the phenomena under study and the type of the facilitator.

The physical learning environment is only one dimension for defining outdoor learning activities. The other two are the goal context and the duration of time.

The goal context of the outdoor learning environment: The goal context is a crucial factor since there is a great difference between a visit that was defined as a fun/social event and a learning event. In the cognitive aspect there also are two

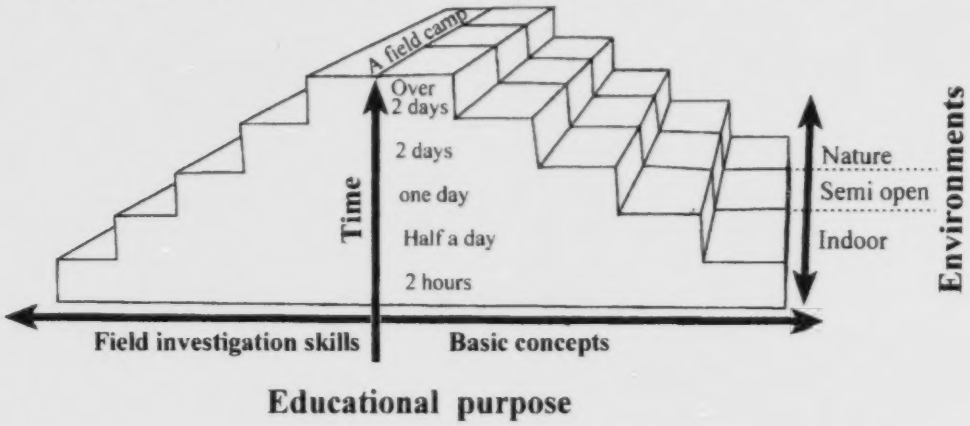

Figure 1: The three dimensional model of identifying a specific outdoor learning event

different objectives in relation to science education: (a) learning of basic concrete concepts through direct interaction with the environment and (b) learning of the field investigation methodology.

Duration of the outdoor learning experience: The amount of time devoted to a field trip greatly influences the preparation of an outdoor event and the type of learning tasks implemented during the event itself. It is possible to distinguish between four types of field trips in relation to the time factor:

a) A short trip of 1-2 hours: Trips of such short duration are usually related to outdoor events that take place in the vicinity of the school. The teacher can integrate this activity easily within the regular studies; the physical environment is well known by the students and the logistic preparation for the event is minimal.

b) A half-day of 4-6 hours: Such trips are usually related to sites such as museums, zoos, science centers, which are not far from the school. However, it requires logistical preparations such as transportation and dealing with the school schedule and preparation of the students for the trip itself (as will be explained later).

c) A whole day of 6-8 hours: Such field trips include visits to natural sites, requiring driving long distances from the school, and sometimes walking for a few kilometers. The preparation for such an outdoor activity is quite complex, since in addition to logistical and educational preparations it requires very careful preparation of the event itself.

d) Two or more days: This usually involves a field camp. This, of course, is the most complex event in terms of preparation and operation. However, it enables the class to deal with more investigative type of learning and to overcome geographical and psychological novelties (as will be explained later).

The above three factors: physical environment, educational goal and duration enable us to define the outdoor learning environment to a three factor model as illustrated in Figure 1. Each box in this model defines a specific outdoor learning event. There is no doubt that there are some similarities among all the different outdoor learning environments. However, it is also likely that each outdoor environment has unique characteristics which curriculum developers and teachers should consider.

3. WHY GO OUTDOORS? (WHAT IS THE ROLE OF THE OUTDOOR ENVIRONMENT IN THE LEARNING PROCESS?)

The "resources invested" in taking a class outdoors are very high in terms of organization, economic, logistics and safety. Therefore, the "educational payoff" should be very high as well. It is suggested that the gap that exists between the high "resources invested" and the generally lower "educational payoff" is equal to the gap that exists between the high potential of the outdoor learning environment and its relatively limited fulfillment. This imbalance might be corrected only through a very clear definition of the unique educational contribution of the outdoor learning environment.

A literature review of any science education journal, within the last three decades, reveals that research concerning the outdoors as a learning environment is located at the periphery of mainstream research. This observation is quite surprising since the role of the out-of-school learning environment is rooted deeply in the philosophy and psychology of education. Important scholars beginning with Rousseau through Dewey, Piaget, and Ausubel have direct and indirect contributions towards promoting the outdoor as an essential learning environment. Although currently, constructivism - a child-centered paradigm - dominates the field of science education, nonetheless, it is hard to understand why so little effort is invested in introducing the out-of-school real concrete world as an available learning environment for teachers and students.

A gap of two centuries and essential differences separate the educational philosophies of Rousseau and Dewey. However, they both can be perceived as the founders of a child-centered philosophy since they believed in children's natural curiosity and the meaningful learning that can grow from it. Rousseau, who believed in spontaneous learning, claimed that children should learn from their direct experiences and not just from books (Egan, 1992). Dewey as well claimed that educators should often use the physical and social outdoor environments as an integral part of the learning process (Rillo, 1982).

Although there is a long-term debate concerning the meaning of "spontaneous learning", there are no arguments concerning the existence of a "natural learning". No one can argue against the fact that young children accumulate huge reserves of very complex knowledge and cognitive understandings before entering kindergarten. Another well-known phenomenon is that there exist children in the markets of third world big cities who although they never attended school, can conduct very complicated mathematical accounts that counterparts in school cannot

perform. Another place where it is still possible to observe natural learning processes is in some areas of Africa and South America where learning and teaching is a daily occurrence amongst the parents and children of primitive tribes.

One way to analyze such natural learning processes is through the following five characteristics: Location of learning; type of learning experiences; relevancy; role of verbal communication; and the subject of learning. Table 1 presents the two edge components of the natural – non-natural learning dimension.

Table 1: Characteristics of the natural vs. non-natural learning dimension.

Characteristics		Natural learning		Non-natural learning
Location		Takes place in a relevant setting to the learnt subject.		Takes place in a closed space that has no relation to any learnt subject.
Type of experience		Includes a concrete experiencing with the subject to be learnt.		Only rarely includes real-life concrete experiences with the subject to be learnt.
Relevancy		The subject to be learnt is highly related to the learner's relevant world.		No immediate relation between the subject to be learnt and learners' relevant world.
Verbal communication		The concrete experience is mediated by verbal communication.		Verbal communication replaces the experience through description of imaginative situations.
Subjects		Learning is idiosyncratic. Rate of progress depends on the learner.		The subject of learning is a large group. It is very difficult to adjust the learning for individuals.

If one would try to locate the schools' ordinary learning today on the scale presented in Table 1, there is no doubt that it would be much closer to the non-natural end than the natural learning end. Moreover, it might explain why so many adolescents all over the world do not like schools--because the common way of teaching in school is the antithesis of their natural way of learning.

Based on the characteristics of natural learning it is suggested that the use of the outdoor learning environment might transform school learning into a more natural process for many children. Having stated this, one should be very careful not to cross the line between pedagogy and demagogy, since there is no way to teach abstract concepts such as the particle model, or the structure and function of cells through the characteristics of natural learning. However, in parallel to the many abstract concepts that any 21st century child of the developed world should know, there are still many concrete scientific concepts and skills that can be learnt in the out-of-school world. As already noted by Orion and Hofstein (1994), Kempa and Orion (1996), Kali, Orion and Eylon (2003) and Dodick and Orion (2003), even very abstract concepts such as the rock cycle and deep time can be internalized if their study includes the concrete component of the outdoor learning environment.

4. THE PREFERRED LEARNING STYLE (S) FOR THE OUTDOOR LEARNING ENVIRONMENT?

I suggest that the main cognitive contribution of the outdoor learning environment is in the concretization aspect that while conducted properly might make the learning process more natural for many students.

The literature provides convincing evidence that outdoor learning activities are beneficial, especially when the teacher combines concrete learning experiences (as an intermediate step) with higher levels of cognitive learning experiences (Vinci, 1969, Folkomer, 1981; MacKenzie and White, 1982). Novak (1976) in describing the implementation of Ausubel's learning theory (Ausubel, 1968) in biology education, points out the need for concrete experiences as a transitional learning stage from primary concepts to secondary concepts. This idea is similar to the "hands-on experiences" which Piaget (1970) identified as very helpful aids for the transition from a concrete to a more abstract level of cognition. The literature suggests two groups of concepts that could be taught on field trips: a) primary concepts derived through sensory-motor experiences and b) phenomena-related concepts which could act as concrete "subsumers" for further learning in the classroom.

Based on Piaget and other developmental psychologists, Lesgold (1998) includes the "concrete vs. abstract knowledge" as one of the basic representation forms of knowledge. However, he claims that for many concepts this difference is not clear since they include both concrete and abstract components. This notion is very important for our ability to use the outdoor learning environment as a key stage for the development of abstract knowledge as well. What we must do is to analyze such concepts for their concrete and more abstract components. Then we should analyze the concrete components to those that might be made concrete through classroom/laboratory activities and those that can be made concrete only in the outdoor learning environment.

Orion (1993) suggested that the main role of the science outdoor activity in the learning process is to provide direct experiences with concrete phenomena and materials. The unique element of the outdoor experience is not in the concrete experiences themselves (which could also be provided in the laboratory and classroom), but the type of experiences. Students could view slides of a dune and investigate quartz grains in the laboratory, but it is only by climbing the steep front slope of a sand dune, that a student could receive a direct sensory-motor experience of learning about the structure of a dune. Experiential (hands on) activities can facilitate the construction of abstract concepts and can serve as subsumers that enhance meaningful learning which provide the framework for long-term memory retention.

Historically, the interactionist view concerning the cognitive contribution of the interaction with the physical environment was suggested by few educators (e.g. Dewey 1896; Lashley 1951) in opposition to the stimulus-response view of behavior. However, only Gibson (1966) developed a systemic theory of direct perception. Gibson argued that perception should be understood as a process of

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The cognitive novelty depends on the concepts and skills that students are asked to deal with throughout the outdoor learning experience. The geographical novelty reflects the acquaintance of the students with the outdoor physical area. The psychological novelty is the gap between the students' expectations and the reality that they face during the outdoor learning event. The psychological novelty of the population in that research reflected their previous experiences in field trips as social events, rather than learning activities.

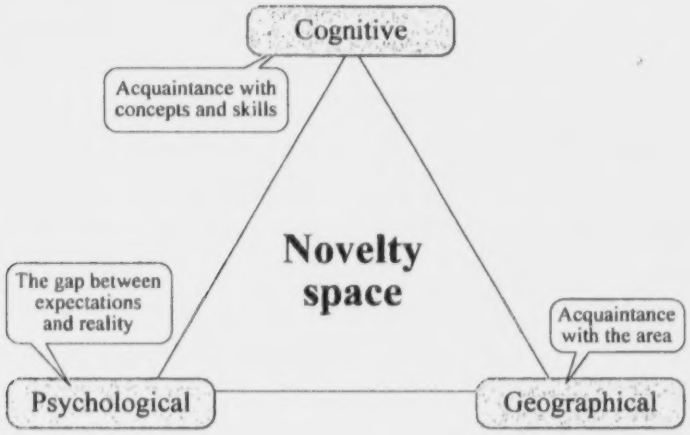

Figure 2: The three dimensions, which identify the novelty space of an outdoor learning activity

The novelty space concept has a very clear implication on planning and conducting outdoor learning experiences. It defines the specific preparation required for an educational field trip. Preparation directly concerned with the three novelty factors can reduce the novelty space to a minimum and thus facilitate meaningful learning during a field trip. The cognitive novelty can be directly reduced by several concrete activities. For example, working with the materials that students will meet in the field, as well as simulation of phenomena and processes through laboratory experiments. The geographic and psychological novelties can also be reduced indirectly in the classroom, first by slides, films and working with maps, and second by detailed information about the event: purpose, learning method, number of learning stations, length of time, expected weather conditions, expected difficulties along the route, etc.

While it is not possible to fully prepare students for a specific outdoor learning event, identifying the specific novelty space of the class involved, and then adapting the level and the length of the learning activity during the field trip, could lead to improvement in the educational value of the outdoor experience.

Orion & Hofstein (1994) argued that in general an outdoor learning activity should be placed early in the concrete part of the learning process, and should be mainly focused on concrete interaction between the students and the environment. The field trip together with the preparatory unit can constitute an independent

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module, which might serve as a concrete bridge towards more abstract learning levels. Thus, a field trip should be planned as an integral part of the curriculum rather than as an isolated activity (Figure 3).

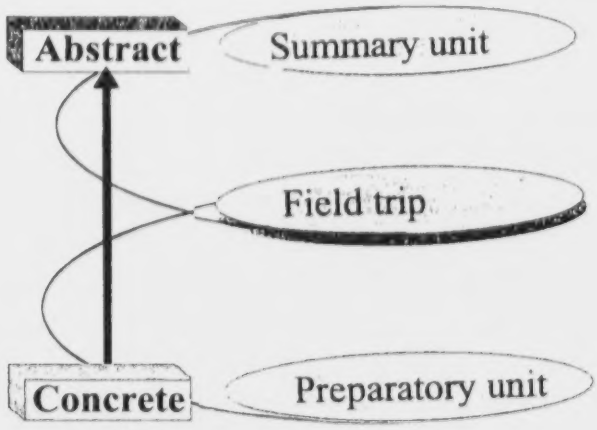

Figure 3: The spiral model of integrating an outdoor learning activity within the indoors-learning process.

6. HOW CAN WE ENCOURAGE THE USE OF THE OUTDOORS AS A LEARNING ENVIRONMENT?

If one accepts that the outdoor learning environment has a central role in the learning process and consequently that it should be an integral part of the learning process, then the teacher must also be an integral part of the outdoor learning activity. However, as already mentioned, teachers (both in the sciences and humanities) all over the world do not perceive the outdoors as a formal learning environment. The common view among teachers is that outdoor events provide social contributions and should be included as enrichment and not as an integral part of the learning process.

Thus, any attempt to increase the profile of the outdoor learning environment within the educational system should involve a major conceptual change or even revolution concerning the teachers' perception of the outdoors as a learning environment. Teachers should be provided through both pre-service and in-service programs with tools to address the questions, which were posed in the beginning of this article such as: WHAT is the outdoor learning environment? WHY use this learning environment? HOW do we use it? Moreover, teachers should be given the tools necessary to conduct the following educational activities: (a) to identify concepts which might be best learnt through a concrete interaction with the environment; (b) to develop concrete outdoor learning activities; and (c) to integrate outdoor learning activities with the learning processes which take place in other environments such as the classroom, laboratory and computer.

In service training projects for teachers should also focus on an educational mapping of the school's immediate surroundings to locate outdoor learning sites. However, changing teachers' attitudes towards outdoor learning environments is a major conceptual change, which might be achieved only through a simultaneous systemic treatment. In other words, such treatment should embrace all the components of the educational system including policy makers; inspectors; principals; the curriculum wing; the in-service and pre-service training departments; the educational administration wing; the evaluation department; the different grade levels of schools (i.e. kindergarten, elementary and secondary); and the regional school branches. All of these components should contribute the atmosphere and the motivation for the teachers to change their attitudes towards the outdoors as a learning environment and of course, to provide them with the needed resources to implement this new and complex teaching strategy.

It is unlikely a Ministry of Education (such as in Israel) on its own will initiate such a reform. The only force, which might prod educational policy towards this goal is the science education research community. Thus, the low profile of the outdoors as a learning environment is a result of a vicious cycle, which begins with the limited research that has been directed towards this area of inquiry by education researchers and ends with the fact that there is a lack of concrete support of the research community that might kick-start such reforms.

Finally, it is crucial to determine the influence of informal bodies such as museums, science centers and field centers on the profile of outdoor teaching, and what should be their role so that this situation may change. During the last 15 years I have conducted a systematic study of such external informal bodies and guides. This study encompassed over 100 naturalistic observations of informal learning activities and hundreds of interviews with teachers, students and museums and field leaders concerning the relationships between an out-of-school informal learning event and the formal science learning in schools. This study was mainly conducted in Israel but also includes a similar but quite limited study in USA, UK, France and Australia. This long-term and broad scale study indicates that there are very similar type of relationships between external informal learning bodies and formal education all over the world. Recently there has been some movement of informal science education towards the formal system. Informal centers all over the world have begun to understand that in order to conduct meaningful visits for students they have to adjust their programs according to the science curricula of the visiting classes and work collaboratively with the schoolteachers.

However, this movement is still quite limited and there are still many traditional informal bodies that are quite disconnected from the reality of schools, their aims and curriculum. This parallelism has a crucial negative influence on both teachers and students. Unknown environments and situations intimidate any human, especially teachers, who have become accustomed towards controlling the learning situation and teaching environments. For them such novelty creates a hostile environment, which makes it difficult to function. Unfortunately, education departments of many (but not all) informal bodies focus on the development of local guides and programs which might replace the teachers. Surprisingly, teachers accept

this situation and as a result they are divorced from this type of learning activity. Since the teachers are usually not involved with the informal programs, such programs are not related to the school's science learning. Consequently, the teachers and the students do not perceive the outdoor learning environment as an integral part of the formal learning and thus another viscous cycle starts.

This viscous cycle creates a sad situation in which even if students experience a meaningful and/or an enjoyable learning event in the outdoor environment they do not connect it with the enjoyment of learning. The most common answer to the following question (which I asked hundreds of students): "Did you enjoy the outdoor event and why?" is "Yes, I enjoyed it a lot because we had a day off". This perception also emerges from the most common statement that teachers say to their students before going outdoors: "If you don't behave then we won't go on the field trip next week..." Such a statement means that the outdoor event is not an integral part of learning, since students usually do not hear statements such as: "If you won't behave well ...we won't go to the laboratory or I won't give you homework."

Informal guides reflect the same attitude. A very common statement of guides that I noticed during my observation of school visits to an outdoor setting is: "Hi, this is not the school; we intend to have a lot of fun here..." The following quote is from an interview with a field leader: "I feel quite insulted when they (the students) call me 'teacher'. I immediately ask them to call me 'guide' or by my first name, but not 'teacher'". This quotation represents a common view that emerged from interviews that were conducted with over 100 informal guides.

In 1995 a new research strand "Informal learning" was established within the National Association for Research in Science Teaching (NARST) of USA. From the year that it was established, this group rejected the suggestion (raised each year during the annual meetings) to change the title of this group, because it contributes to the negative connotations as explained above.

It is rather odd that the same group which promotes the understanding that learning can take place anywhere at anytime also promotes the distinction between informal and formal education. Unfortunately, this perception pushes the teachers out of the outdoor learning process and perpetuates the perception that learning is something (usually) boring that one does in school while an outdoor activity is fun partly because it is not connected with the school learning.

In order to stop this vicious cycle the informal bodies should focus on providing in-service training programs for teachers to teach them how to independently use the outdoors as a learning resource. Such programs will also assist them to integrate learning in school with the resources of a specific outdoor setting.

7. SUMMARY

The outdoor environment to a large degree is a wasted learning and teaching resource. Educational systems around the world fail to fulfill the high cognitive potential of the outdoor learning environment. The science education research literature demonstrates that there are solid reasons for using this environment in the

learning process. Furthermore, it also includes practical models for integrating the outdoor as an integral learning environment within the regular science curricula. However, such knowledge is shared by a relatively small number of science educators. In order to upgrade the status of the outdoor learning environment so that it is comparable to the lab and computer environments, science teachers should first undergo a deep conceptual change concerning their attitudes towards the outdoors as a learning environment. Following such conceptual change, massive in-service and pre-service programs should be provided to science teachers so that they can build the teaching skills needed for using the outdoors properly. In addition a massive curriculum development effort is also required.

Such large-scale reform has a limited chance of success unless it encompasses all the facets of the educational system. However, the motivation for an educational system to start such a large costly process is highly dependent on the support of the science education research establishment.

Another key factor influencing the science teachers' ability to use the outdoor learning environment is the informal education establishment. There is a strong need to close the gap between the informal and formal education so that they become an integrated system. Following this new insight there should be a stronger effort at transforming outdoor sites into friendly and available teaching resources - an immediate extension of the laboratory and the classroom learning environments.

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CHAPTER 5: TAIWAN'S 1-9 GRADES SCIENCE AND TECHNOLOGY CURRICULUM STANDARDS AND GSL

Chun-Yen Chang, National Taiwan Normal University, TAIWAN, R.O.C.

1. INTRODUCTION

Curriculum reform has gained much attention from teachers and researchers in science education all over the world. Taiwan is also on the same trail to develop the new *1-9 Grades Curriculum Guidelines* (Ministry of Education, [MOE], 1998) for the primary and secondary levels with the goals of reforming pre-college education. According to the curriculum guidelines, there are seven fields of study including Art and Humanity, Health and Physical Education, Language, Mathematics, Science and Technology, Social Sciences, and Extracurricular activities. Permeating throughout these seven fields of study are various areas of interest such as career planning, environmental conservation, gender equity, human rights, and information and communication. Since 1998, many scientist, science educators, and science teachers have been involved in developing the *Science and Technology Curriculum Standards* (SaTCS, MOE, 2001) for the study field of science and technology, attempting to cover the traditional subject matters such as biology, chemistry, Earth sciences, physics, and technology in an integrated sense.

The new science and technology curriculum standards aim at a systematic way of developing student's understanding and appreciation of three interactions including; human being and the individual, human being and the society, as well as human being and the nature. Some of which are generally aligned with the philosophical essence and foundations of Earth Systems Education (ESE) or Global Science Literacy (GSL). Moreover, ESE/GSL has its practical significance to the structural, componential, and implementing aspects of the SaTCS and to the future development of pre-college science curricula in a broader sense in Taiwan.

This chapter is organized through the following:

- calling attention to the importance of the inclusion of ESE or GSL into the forthcoming science curricula of Taiwan.
- introducing the developmental process and major components of the SaTCS, and making a critical analysis between the SaTCS and GSL.
- reporting a survey result regarding teacher's perceptions of the SaTCS that features elements sympathetic to GSL.
- providing some exemplary GSL-inspired curriculum and instructional modules that have been successfully implemented in the secondary schools of Taiwan

Hopefully, this chapter can shed some lights on the future development of the GSL-based science curricula, instructional modules, and teacher preparation programs from an international perspective and context.

2. A BRIEF SKETCH OF TAIWANESE EDUCATIONAL SYSTEM AND EARTH SCIENCE EDUCATION

It is necessary to elaborate upon the educational system and Earth science education origins of Taiwan before discussing the place of the SaTCS and GSL's practical significance in the primary and secondary science classrooms. There are five levels in the contemporary educational structure in Taiwan: Kindergarten (K), Elementary School (1-6), Junior High School (7-9), Senior High School (10-12), and College or University. Although higher education administration in Taiwan differs greatly from the USA system at the national level, it is similar to the USA system at the state levels, as well as the British, French, German, and Swedish systems.

After junior high school, students who wish to attend college in the future must take the annual Entrance Examination for Senior High Schools (EESHS, before year 2000) or Basic Competence TEST for Senior High Schools (BCTEST-SHS, twice a year effective in year 2001) in order to enroll in a high-ranking senior high school. Then, senior high school students, seeking college studies, must take another annual national competitive entrance examination, the Joint Entrance Examination of Universities and Colleges (JEEUC, before year 2001) or Basic Competence TEST for Universities and Colleges (BCTEST-UC, twice a year effective in year 2002). In traditional China, this kind of competitive selective process has survived for many years because it provided an opportunity for low-ranking social groups to move upwards in society.

The EESHS/ BCTEST-SHS and JEEUC/ BCTEST-UC consist of a 2-day written test program, covering subjects such as Chinese, English, Mathematics, Natural Sciences (Physics, Chemistry, Biology, and/or Earth Sciences), and Social Sciences. To be prepared for these important entrance examinations, students must work on many exercises and problems and take thousands of tests in secondary school. Owing to the importance of the entrance examinations to the future of students, developing their problem solving skills and improving their performance achievement has long been a major goal among science educators and science teachers in Taiwan.

Addressing the needs for students to understand the Earth and the increasing environmental issues around us, the Ministry of Education in Taiwan first included a required Earth science course (2 hours per week initially) in the junior high school science curriculum (ninth grade) in 1986, and further incorporated an Earth science subtest into natural science subjects on the annual Entrance Examination for Senior High School (EESHS) in 1987. The inclusion of an Earth science subtest encouraged parents, teachers, and students in Taiwan to pay attention to the science of the Earth, which deals with the materials of our planet and the processes, which bring about change. The Earth science curriculum consists of four major topics: Astronomy, Geology, Meteorology, and Oceanography. Both of the BCTEST-SHS and BCTEST-UC incorporate the subject of Earth sciences into the Natural Sciences test.

3. THE IMPORTANCE OF THE INCLUSION OF EARTH SYSTEM EDUCATION INTO THE SCIENCE CURRICULUM OF TAIWAN

In all respects, Taiwan is not and should not be alone in terms of reforming science education and incorporating Earth science or Earth systems education (ESE) into the contemporary science curriculum. Since learning Earth science not only interests students in probing the mysteries of nature, but also can stimulate students' concern for environmental devastation around the world such as acid rain, global warming and climate change, El Nino's influence, ozone depletion, and groundwater pollution. Earth science, which consists of geology, meteorology, astronomy, and oceanography, is one of the science subjects most relevant to students' everyday lives. Accordingly, the *National Science Education Standards* in the USA (NRC, 1996) embraces "Earth and Space Science" as one of the eight categories of content standards along with Physical Science and Life Science. A detailed examination of the curriculum frameworks that served as the guideline for designing the achievement tests of the IEA's (International Association for the Evaluation of Educational Achievement) TIMSS (Third International Mathematics and Science Study) in 1994-1995 also revealed that Earth science is formally taught at the secondary school levels in various countries (Robitaille et al. 1993).

Earth system sciences and system science methods are emerging as important science disciplines and science methodologies due to human awareness of the world's deteriorating land, water and climate; yet, for the past decades its significance has not been reflected in the traditional "reduction" type of science curricula, as described by Mayer and Kumano (1999).. As a matter of fact, the discipline-oriented science curriculum and "reduction" science methodology have not only dominated in the USA but also in Taiwan for many years. Mayer and Fortner (2002) made it clear that, "the science curriculum in the secondary schools of the USA and through its influence, in many countries around the world, came to focus on the type of science supportive of Cold War technology, that of the physical sciences". Unfortunately, Taiwan is exactly one of the countries that closely followed the steps of the USA in the past.

The interdisciplinary and integrated nature of Earth science is unique among other sciences . Aldridge (1993) stated that, "Chemistry and physics are fundamental to an understanding of the life sciences. And chemistry, physics, and the life sciences are fundamental to an understanding of the Earth and space sciences" (p. 27). However, primary and secondary programs in Taiwan generally ignore those sciences and methods that teach us about how the Earth System functions and how to study science in a systematic and integrated way, but rather only concentrate on those seemingly fundamental science knowledge and "reduction" science methodologies.

3. THE CONTEMPORARY CALLS FOR AN INTEGRATED SCIENCE CURRICULUM AROUND EARTH SYSTEMS THEME

There is a contemporary call for an integrated science curriculum at the elementary and secondary levels throughout the world. The *National Science Education Standards* in the USA describe that

> LESS EMPHASIS ON: Studying subject matter disciplines (physical, life, earth sciences) for their own sake
> MORE EMPHASIS ON: Integrating all aspects of science content
> (National Research Council, [NRC], 1996, p. 113)

The British science educators compiled a report entitled *Beyond 2000: Science Education for the Future* (Millar and Osborne 1998), which highlights the integration of science curriculum as the following:

> The science curriculum should provide young people with an understanding of some key ideas-about-science ... ... 5.3 INTEGRATING VARIOUS ASPECTS OF THE CURRICULUM□It is essential that the different elements of the science curriculum discussed in section 5.2 are integrated into a coherent programme. (p. 2020)

The latest released *1-9 Grades Curriculum Guidelines* in Taiwan (MOE, 1998) also distinctively noted that, "The seven fields of study highlight the major learning contents instead of individual subjects that students should learn in the primary and middle schools, therefore, the individual field of study is supposed to be a sound program integrating traditional subject matters with an emphasis on collaborative teaching efforts among teachers who were even trained from different background of disciplines." (p. 6).

Even the American Association for the Advancement of Science (AAAS 1993, p. 66) recently developed the *Benchmarks for Science Literacy*, to express some integrated science ideas; they specifically state:

> An integrated picture of the Earth has to develop over many years, with some concepts being visited over and over again in new contexts and greater detail. Some aspects can be learned in science, others in geography; some parts can be purely descriptive; others must draw on physical principles (p. 6).

The aforementioned perspective is very similar to the ideas proposed by Mayer (1997). Mayer (1997, p. 102) has specifically proposed that "Earth System as the organizing theme for the development of integrated science curricula at the elementary through high school levels." Therefore, Mayer's (1995) call for an integrated science curriculum building around a unifying theme, the Earth system, provide excellent solutions to the past failed attempts at implementing integrated science curricula, which were in essence discipline-oriented framework and reduction-type science methodology in the primary and secondary schools.

5. THE DEVELOPMENT AND COMPONENTS OF THE SaTCS IN TAIWAN

In response to the contemporary calls for an integrated curriculum throughout primary and secondary education, the MOE of Taiwan commenced its own educational reform in 1997 and launched the first documentation in a series entitled the new *1-9 Grades Curriculum Guidelines* (MOE, 1998). The guidelines particularly recognize seven major fields of study at the elementary and secondary levels (Art and Humanity, Health and Physical Education, Language, Mathematics, Science and Technology, Social Sciences, and Extracurricular activities) and strongly urge integration among a variety of subject matters within each field of study. Since then a range of science experts, science educators, and science teachers have been involved in developing the SaTCS (MOE, 2001) for the study field of science and technology, which attempted to integrate the traditional subject matters such as biology, chemistry, Earth sciences, physics, and technology into one major field of study.

There are six objectives proposed by the SaTCS; (1) to grow students' interest and enthusiasm in science and develop their autonomous learning habits; (2) to help students acquire fundamental knowledge and inquiry methods in science and technology and apply those knowledge and methods to their daily life; (3) to increase students' constructive perceptions of cherishing environment, treasuring resources, and respecting lives; (4) to expand students' skills of communicating, cooperating, and getting along with others; (5) to develop students' abilities of independent thinking and problem solving and stimulate their creativities and potentials; and (6) to promote students' awareness on interactions between humanity and technology. Besides the six objectives, eight categories of scientific literacy were also developed to serve as indicators of science learning outcomes. These indicators are process skills, science and technology knowledge, nature of science, development of science and technology, scientific attitudes, intellectual ability, science applications, and design and create.

The six objectives could all be well achieved by adopting an integrated curriculum organized around the Earth-system theme. Because Earth system science, unlike the discipline-oriented approach to the study of individual separate or even in-depth subject contents, takes an interdisciplinary and system science approach, the student learns in a way which is more closely related to their daily lives. Much contemporary educational research has demonstrated that pupils can memorize, comprehend, and learn things more easily in the context which is more meaningful and interesting to them (Iran-Nejad, Mckeachie & Berliner, 1990, p. 511). With the Earth system science, students would simply develop their interest and enthusiasm in science (objective #1 of the SaTCS) with an integrated-system approach. Using the concept of Earth system and its processes as the organizing theme, basic knowledge and inquiry methods could not only be learned more meaningfully by the students (Mayer, 1995) but also be applied to students' daily life without much difficulty (objective #2 of the SaTCS).

There are seven Earth Systems Understandings included in the framework of Earth systems education, as shown in Table 1 of Chapter 1 in *Global Science*

Literacy (Mayer and Tokuyama, 2002). Understanding #2 emphasizes, "Human activities, collective and individual, conscious and inadvertent, affect planet Earth" and it's sub theme, "The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide." This understanding is essentially consistent with the third objective of the SaTCS, i.e., to increase students' constructive perceptions of cherishing environment, treasuring resources, and respecting lives. It is anticipated that students' skills of communication and cooperation, and their abilities of independent thinking and problem solving will be more easily developed in the integrated and holistic Earth-system science approach (objective #4 & #5 of the SaTCS). Lastly, Earth system science focuses not only on interacting systems of Earth but also on human and technology impacts on the Earth and our environment, as suggested by the Understanding #3 of ESE, (The use of technology may have benefits as well as unintended side effects), which should also facilitate in promoting students' awareness on interactions between human and technology (objective #6 of the SaTCS).

The major characteristics of the SaTCS were to reduce the content of learning materials with the goal of motivating students to learn science and to help students to apply what they have learned in the science classrooms to their everyday life (Chang & Chiu, 2000). There are four main themes to form the curriculum content standards and each theme contains its own sub-themes and contents. Table 1 presents the components of the SaTCS (Chang & Chiu, 2000). The first theme "Compositions and characteristics of nature" and the second theme "Interactions in nature" are not only integrated subjects but also are consistent with the Understanding # 4 of ESE (The Earth system is composed of interacting subsystems of water, rock, ice, air, and life: Each component of the Earth system has characteristic properties, structure, and composition that may be changed by interactions of subsystems). Whereas the rest of major themes entitled "Evolution and continuity", "Life and environment", and "Lifelong development" are in agreement with Understanding #5 (Planet Earth is more than 4 billion years old and its subsystems are continually evolving), Understanding #2 (Human activities, collective and individual, conscious and inadvertent, affect planet Earth), and Understanding #3 (The development of scientific thinking and technology increases our ability to understand and utilize Earth and space). After carefully examining this table and the seven understandings of ESE, it can be concluded that the four major themes and thirteen sub-themes are generally aligned with each other. Therefore, future curriculum development and planning based on the SaTCS can be more practicably and successfully implemented in the primary and secondary schools by adopting the GSL model as proposed in Table 1 of Chapter 1. (Mayer and Tokuyama, 2002)

Table 1. The components of the SaTCS

Themes	Sub-Themes	Contents	
Compositions and characteristics of nature	The Earth environment	110	Compositions of the Earth (rocks, water, air)
		111	The Earth and space
	Lives on the Earth	120	Uniformity in lives
		121	Diversity in lives
	Compositions and properties of matter	130	Structure and function of matter
		131	Forms and properties of matter
Interactions in nature	Change and stability	210	Changes in the Earth surface and crust
		211	Changes in weather
		212	Days/nights and seasons
		213	Constancy and accommodation in body
		214	Heat and temperature
		215	Motions and force
		216	Sound, light and wave
		217	Energy form and transform
		218	Chemical reaction
		219	Chemical equilibrium
	Interactions	220	Global warming
		221	Animal behaviors and living things' reaction to environmental stimulus
		222	Electricity and magnetism
		223	Gravity
		224	Water and solutions
		225	Oxidation and reduction
		226	Acid, base, and salt
		227	Organic compounds
	Structures and functions	230	Structures and functions of plants
		231	Structures and functions of animals
Evolution and continuity	Continuity of lives	310	Reproduction, genetics, and evolution
	The Earth history	320	Stratigraphy and fossils
Life and environment	Application of technology	410	Food
		411	Materials
		412	Applications of mechanics
		413	Electricity and its applications
		414	Information and communication
		415	Living
		416	Transportation
	Environmental protection	420	Natural hazards and mitigations
		421	Environmental pollution and preventions
Sustainable development	Preservations of ecology	510	Lives and environment
		511	Human beings and nature
		512	Preservation and usage of resources
		513	Exploitation and usage of energy
	Science and humanity	520	Development of science
		521	Beauty of science
	Creativity and civilization	522	Ethics of science
		530	Creativity and Design
		531	Technology and civilization

6. AN INITIAL SURVEY ON SCIENCE TEACHERS' PERCEPTIONS OF THE SaTCS

In order to get insights and feedbacks from scientists, science educators, science teachers, and school administrators all over the country, four special sessions of "The SaTCS Hearings" were held in the north, central, south, and east regions of Taiwan in June 1999. In addition, the first drafts of the SaTCS along with an opinion questionnaire were sent out to the elementary and junior high school science teachers to acquire their professional opinions and comments on the SaTCS at the end of school semesters in 1999.

A Likert-style survey (Likert, 1932), Science Teacher Opinions Questionnaire (STOQ), with a five-item semantic-differential scale was developed and administered to elicit teachers' opinions on the content of the SaTCS. Each STOQ item comprises a statement and several responses which were differentiated on a scale that ranged from 1 - "strongly like" or "strongly agree" to 5 - "strongly dislike" or "strongly disagree". A total of ten question items, including six teacher-comment sections dealing with the goals of the SaTCS, viabilities of the SaTCS's goals, indicators of abilities for each stage, and contents of the SaTCS, were included in the questionnaire. Likert-style questions and teacher statements on the comment section were intended to explore teacher perceptions of the SaTCS in more depth.

The demographic characteristics of the science teachers participating in the initial survey indicate an experienced, well educated, and male dominated group (Table 2). The demographics of the participants consist of 65.3% male science teachers and 34.7% female science teachers. Almost Fifty-nine percent of the teachers are elementary-school science teachers and thirty-eight percent of the teachers are teaching in the junior high schools. Almost eighty-eight percent of the teachers had at least four years of teaching experience while only twelve percent of the teachers had less than four years of experience teaching science. Seventy-eight percent of the participating teachers held a bachelor degree in science, and surprisingly one fifth of the science teachers held a master degree in science. The educational background of science teachers reflects a good quality of professional training in Taiwan.

Table 2. The Demographic Characteristics of Participating Science Teachers in the Survey

Schools		Age		Gender		Years of teaching experience		Highest degree attained	
Elementary	Junior high	Below 40	Above 40	Male	Female	≥ 4	< 4	Bachelor	Master
58.9%	38.1%	55.1%	44.9%	65.3%	34.7%	87.7%	12.3%	78.4%	20.8%

Teacher's responses on the STOQ are positive (Table 3). For question 1, "I think that the goals of the SaTCS are aligned with less content, close relation to students' everyday life, integration of science, and application of science", 90.2% of teachers had a positive perception toward the goals of the SaTCS and only 2.1% of teachers had negative feelings toward the goals of the SaTCS. Responses from question 3, "I think that goals of the SaTCS are viable", show that almost 88.4% of teachers agreed upon the viability of the SaTCS's goals and only 7.8% of teachers disagreed with the viability of the SaTCS's goals. Almost 86% of teachers think that it is appropriate to categorize scientific literacy into the eight main themes and only 2.6% of teachers disagree with that; according to the responses obtained from question 6, "I think that it is appropriate to categorize scientific literacy into the eight main indicators". A lot more teachers (81.5%) had positive attitudes toward the indicators of abilities for each stage in comparison with those of teachers who indicated negative responses (3.5%) gathered from question 9, "I think that indicators of abilities are appropriate for each stage". The results of this initial survey suggests that science teachers hold very positive attitudes toward the goals of the SaTCS, the eight themes of scientific literacy, and indicators of abilities for each stage, and contents of the SaTCS. Teachers' responses are also generally aligned with the attempted proposal of GSL, which emphasized an integrated, systematic approach of studying science.

Table 3. Teacher responses on the Science Teacher Opinions Questionnaire

Survey questions		Frequency of responses			Percentages of responses		
#	Key word	Agree or like	No opinion	Disagree or dislike	Agree or like	No opinion	Disagree or dislike
1	Goals of the *SaTCS* aligned with less content, close relation to students' everyday life, integration of science, and application of science	210	18	5	90.2	7.7	2.1
3	Viability of the *SaTCS*'s goals	205	9	18	88.4	3.9	7.8
6	Appropriateness of categorizing scientific literacy into the eight main indicators	197	26	6	86	11.4	2.6
9	Appropriateness of indicators of abilities for each stage	185	34	8	81.5	15	3.5

7. SEVERAL SUCCESSFUL IMPLEMENTATIONS OF THE GSL-INSPIRED CURRICULUM OR INSTRUCTIONAL MODULES IN TAIWAN

Various attempts have been tried to incorporate Earth-system themes and system science methods into developing integrated science curriculum and instructional modules for the secondary schools of Taiwan. The implementations of these GSL-inspired curriculum or teaching modules were all proven to be very successful. For example, an inquiry-oriented instruction organized around "Earth-Sun-Moon" theme in alignment with the Understanding # 6 of the Earth Systems Education, "Earth is a small subsystem of a solar system within the vast and ancient universe" and its sub-theme "The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes", has been found to be fruitful in promoting student's science achievement and attitudes toward science (Chang & Mao, 1999). Another study employing a problem-solving-based instruction, organized around a "plate tectonics" theme, in line with the Understanding # 4 of the Earth Systems Education, "The Earth system is composed of interacting subsystems of water, rock, ice, air, and life" and its sub theme "Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface", has also shown a significant improvement of student achievement and modification of their misconceptions (Chang & Barufaldi, 1999).

We have also developed a computer-assisted instruction (CAI) on the topic of "Human activity and its impacts on the debris-flow hazards" organized around another important Earth-system theme: Natural hazards and mitigation (Chang, 2001a, 2001b, 2002). This topic has also been proposed by the Understanding # 2 of ESE, "Human activities, collective and individual, conscious and inadvertent, affect planet Earth" and its sub theme "The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide."

In this GSL-inspired computer-assisted instructional tutorial, students were first shown a video clip of the debris-flow hazard occurred in Nan-Tou Province of Taiwan in 1996. Then they were asked to identify facts associated with this specific problem on the natural hazard, and they were required to find out possible factors that might cause this hazard through guided inquiry provided by the computer program. Students were subsequently encouraged to prepare and implement their plans by analyzing and investigating the research questions, i.e., the factors causing the debris-flow hazards and collect necessary information in association with the debris-flow hazard. Students also need to go through a virtual field trip to conduct geological investigations provided by the CAI and to find out the solutions to the debris-flow hazard problems. Finally, student prepared final reports of their work and presented project results to their classmates by explaining and communicating with each other. The "human activity and its impact on the debris-flow hazards" CAI was found to have promise in supporting students' learning of Earth science and leading to improved student achievement and attitudes toward the subject matter (Chang, 2001a, 2001b, 2002)

Three Earth-System-Integrated Teaching Instructional Modules (ESITIM) for the secondary schools were developed thanks to a three-year special grant from National Science Council of Taiwan (grant no. NSC 89-2511-S-003-144), which

were also inspired by the philosophy and essences of Global Science Literacy. The GSL-based instructional modules cover the following four themes: 1) evolution and continuity, 2) dynamic-interacting subsystems of the Earth, 3) Earth resources, and 4) natural hazard and its mitigation. A GSL approach, as noted in Table 1 of Chapter 1, and a four-step learning cycle model (Engage, Explore, Analysis/Explain, Apply/Evaluate, EEAA) were also adopted (Chang & Lai, 2001). Field test implementations of the Earth-system integrated teaching modules in the secondary classrooms were all quite successful and encouraging.

Earth-System Earth-Resources Instructional Module (ESERIM) was the first instructional module developed during the first year project. This module is based upon the Understanding # 2, "The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide." We examined the effects of the ESERIM on 11th graders' science learning in three secondary schools of Taiwan. Many positive responses were expressed by participating students, such as "the instruction is fairly interesting to me and motivates my own learning", "I have learned a lot of things related to my daily life", "I learned how to approach the issues of environmental pollution from different perspectives", and "I was aware of the dilemma between economic development and environmental preservation", which were all strongly aligned with the design and objectives of the ESERIM (Chang and Lai, 2001) and the foundations of GSL.

In addition, we have also conducted in-depth semi-structural interviews with three participating teachers after they implemented ESERIM in their classrooms, with the aims at exploring their perceptions toward the ESERIM. The analyzed data indicated positive and supporting attitudes of the teachers toward the ESERIM and optimistic opinions about the viability of implementing this type of Earth-system integrated science curriculum in senior high schools. Importantly, teachers expressed advantages of the ESERIM in terms of encouraging students to respect and value other's ideas, look at problems from different perspectives, work together with their peers to solve problems, and change their ways and attitudes of pursuing knowledge. The findings suggest that implementing the Earth-System integrated theme has the potential to serve as a model for future development of an integrated curriculum and instruction in Taiwan (Lai and Chang , in press).

8. CONCLUSION

Curriculum reform has been a significant emphasis for most of countries all over the world for the past few years. It was the first time for Taiwan to develop a new Science and Technology Curriculum Standards for grades 1 through 9 compulsory educations. The SaTCS features less science content with the aim at motivating students to learn science and encouraging students to apply science to their everyday life. The results of an initial survey have also revealed that many elementary and junior high school science teachers hold relatively positive perceptions toward the SaTCS that is practically well aligned with the philosophical essence and foundations of Earth Systems Education or Global Science Literacy (GSL). Moreover, implementations of several GSL-inspired curriculum or instructional

modules in the secondary schools of Taiwan have all demonstrated promise in improving students' abilities both in their cognitive and affective domains.

Lastly, but not the least, allow me to conclude my chapter by borrowing some of Mayer's words (1997) regarding the necessity of Earth-system science approach in the primary and secondary science curriculum not only in Taiwan but also worldwide, since I could not possibly express it any better.

> Children of all nations experience weather, and while each child's habitat is unique, many observe flowing streams and rock materials as parts of their daily environment, and they often appreciate the beauty of sunsets, the power of storms, the sparkle of snow crystals in winter, the tranquility of a mountain scene, or the colors of deciduous trees on a bright autumn day. A science curriculum organized around the student's natural environment provides a common subject for study in all cultures. Improving our knowledge of our climate system and of ways to ameliorate its disruption (Mayer, 1997, p.102).

Being encouraged and impressed by the successful implementations of the GSL-inspired instructional modules in Taiwan, I sincerely believe that the dream of many countries throughout the world adopting and employing an Earth-system integrated science curriculum in science classrooms will finally come true.

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CHAPTER 6: A COMPARISON OF KOREAN AND AMERICAN SECONDARY SCHOOL STUDENTS' UNDERSTANDING ABOUT EARTH SYSTEMS CONCEPTS AND ENVIRONMENTAL TOPICS

Hyonyong Lee, The Ohio State University, USA.

1. INTRODUCTION

Curriculum developers and science educators in Korea have expressed some interest in Earth Systems Education and ideas as a possible structure for aspects of science content of the Korean national curricula. Earth Systems Education (ESE) as the science foundation of Global Science Literacy focuses on interdisciplinary aspects not only within science but of science with the other school subjects such as environment and social sciences. ESE is a concept for the organization of all science curricula at the pre-college level. ESE curricula emphasize the concepts of Earth systems, solar system and universe. As Lee (2002) observed, ESE has been implemented in different ways at a number of schools across the United States since 1989. Several countries have paid attention to ESE and the Earth systems approach to reform their science curriculum. Earth systems as a unifying theme of science has become widely accepted and has considerably influenced the restructuring of science curriculum and curriculum development.

This study primarily investigates the degree of both Korean and American students' self-reported knowledge and self-perceived significance levels associated with selected Earth systems concepts and selected Earth systems and environmental topics. It is designed 1) to investigate Korean and American middle school students' self-reported knowledge and perceived significance on Earth systems concepts and the selected Earth systems and environmental topics; and 2) to compare students' self-reported knowledge and perceived significance levels, and their primary information source on the topics. The specific questions are as follows:

1. How do self-reported knowledge and perceived significance levels toward Earth systems concepts and Earth systems and environmental topics differ with country?
2. What is the primary information source about the issues most used by Korean and American students?

2. METHOD

2.1. Subjects

Since this study was an exploratory study, we are not attempting to generalize our findings. The selection of schools was one of convenience. The data for this study were collected from two middle school student groups in Bucheon, Korea and Columbus, Ohio, USA. Both schools are located in similar sized metropolitan areas. The subjects consisted of 110 Korean students and 102 American students, born in either 1986 or 1987, drawn randomly from the two schools. The Korean subjects

comprised 58 males (53%) 52 females (47%), and the American subjects comprised 51 males (50%) and 51 females (50%). The population of the American middle school was multi-cultural, consisting of Caucasian, African American, Asian, and Hispanic students (Ohio Department of Education, 2000). However, there was no cultural diversity among the Korean students. In addition, the American students had been exposed an Earth Systems Education curriculum for two academic years.

2.2. Instrument

The survey instrument was developed through modification of a questionnaire from Lee (2000). The survey was designed to explore and identify any quantitative evidence related to students' self-reported knowledge and self-perceived significance levels of Earth systems concepts and environmental topics, and their primary information sources on those topics. For each item, there was a Likert-type rating scale of 1-6 (e.g., for knowledge section, 1 = not at all knowledgeable, 6 = very knowledgeable).

One of the important features of ESE for school science curriculum is an emphasis on the use of Earth and Earth's subsystems as the context for the content to be covered (Mayer et al., 1992). Major content in ESE is highly related to environmental issues and topics and Earth systems concepts. Thus, in the survey instrument, nine classical, global and local environmental topics and issues were selected from several previous studies (Lee, 2000; Lee & Fortner, 2000; Riechard & McGarrity, 1994; Riechard & Peterson, 1998) and from one popular environmental science textbook: *The Blue Planet: An Introduction to Earth System Science* by Skinner and Porter (1995). The selected topics included acid rain, air pollution, water pollution, global warming, introduced species, oil spills, ozone hole, trash disposal, and El Niño. In addition, 17 Earth systems concepts and topics were selected on the basis of the Framework of the Seven Earth Systems Understandings (See Appendix A). For instance, the instrument includes three Earth systems concepts and topics related to the Earth Systems Understanding #5 (ESU#5) in the ESE Framework: Earth history, evolution, and cycles in nature (e.g., water cycle, rock cycle, carbon cycle, etc.). ESU#5 focuses on the great age of the Earth and the constant evolution of subsystems through time. The three concepts and topics were identified on the following basis of four specific descriptions:

> **Understanding #5**: Planet Earth is more than **4 billion years old** and its subsystems are continually evolving. **[Earth history]**
> - **Earth's cycles and natural processes** take place over time intervals ranging from fractions of seconds to billions of years.
> - Materials making up planet Earth have been **recycled** many times. **[cycles in nature]**
> - Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
> - **Evolution** is a theory that explains how life has changed through time. **[evolution]**

Content validity of the questionnaire was established by the use of expert judges who were two professors and five doctoral students who were studying either science education or environmental education. Specifically, review and assessment were performed with two middle school teachers both during and after the

development of the instrument. They also determined that the topics were at the appropriate level for middle school students. All advice and comments were reflected in the content of the instruments.

A pilot test was conducted with 37 subjects, consisting of 20 female and 17 male respondents. Participants in the pilot test were volunteers solicited from a sample frame that consisted of American middle school students. Some students understood some topics slightly differently because of the naming of the emerging environmental issues. In other words, the naming of topics might not get to what we want in some cases. For example, "Loss of biodiversity" has a large context, but some middle school students did not understand it to mean loss of animals and plants in any way, but rather as total extinction. Therefore, we changed this issue to "Endangered species." The internal reliability of the final instrument was calculated using Cronbach's (1984) Coefficient Alpha for both before items modified (Alpha = .91) and after items modified (.92).

3. PROCEDURE

The questionnaires were distributed and the directions were read aloud for students. Students completed the questionnaires in their own classrooms (most students took between 20 and 25 minutes). Students were encouraged to ask questions about directions and words that they did not understand. Each student's response to each item was recorded, and the ratings were summed to get a total score on each item.

The computer program, Statistical Program for the Social Sciences (SPSS Ver.10.0 for MS Windows) was utilized for statistical analyses. Descriptive statistics were used to describe, analyze, and interpret the data that had been collected from the students in this survey. Multivariate analyses of variance (MANOVA) were conducted for the following two sets derived from the survey: (1) self-reported knowledge and self-perceived significance levels of 17 selected Earth systems concepts and topics; and (2) self-reported knowledge and self-perceived significance levels of 9 selected Earth systems and environmental topics. If MANOVA was significant at a 95% confidence level, the follow-up univariate tests (ANOVAs) were conducted to determine the differences between Korean and American students in the self-reported knowledge and self-perceived significance level mean scores of the seventeen concepts and nine topics.

Regarding p value, a Bonferroni's inequality principle was used to determine significance for all of the analyses (Klockars & Sax, 1986). To ensure an overall significance level of α, each of the tests should reach significance at the α/c level where c is the total number of comparisons made (Zolman, 1993). Thus, significance was determined at the 95% confidence level ($\alpha = 0.05/2 = .025$) for univariate ANOVAs.

4. RESULTS

A multivariate analysis, Wilke's lambda, was used to determine the significance level of mean differences between Korean and American students for the dependent variables. MANOVAs were conducted for the two sets derived from the survey: (1) self-reported knowledge and self-perceived significance levels of 17 Earth systems concepts and topics, and (2) self-reported knowledge and self-perceived significance levels of 9 selected Earth systems and environmental topics. The values of Wilke's lambda for the first MANOVA ($\Lambda = .317$, $F_{1, 204} = 14.857$, $p < .000$) and second MANOVA ($\Lambda = .217$, $F_{1, 193} = 16.852$, $p < .000$) are significant. In this section, each of the follow-up univariate analyses (ANOVAs) for self-reported knowledge and significance are presented for both Korean and American students.

4.1. Self-reported knowledge and perceived significance levels on 17 Earth systems concepts and topics in Earth Systems Education

The *F* values from the univariate analyses (ANOVAs) were utilized to determine if a statistically significant difference existed at $\alpha < .025$ or better (95% confidence level) between two country students for each knowledge and significance level mean score for the 17 Earth systems concepts and topics (dependent variables). With regard to students' self-reported knowledge level, all mean scores of seventeen topics for the Korean subjects were significantly lower ($\alpha < .025$) than those of American subjects (see Table 1). Before the survey, it was expected that Korean students would have lower self-reported knowledge mean scores for several Earth systems concepts and topics because they had never been exposed to Earth Systems Education before. However, the results showed the unexpected very low self-reported knowledge mean scores for all seventeen concepts and topics.

Table 1. Comparisons of mean scores of self-reported knowledge, and perceived significance levels of 17 Earth systems concepts and topics between two countries

Earth systems concepts and topics (ESU#)	Self-reported Knowledge				Self-perceived Significance			
	Korean		American		Korean		American	
	M^1	*SD*	M^1	*SD*	M^2	*SD*	M^2	*SD*
Value of Earth (#1)	4.05	1.21	4.87	1.11	5.28	1.04	4.79	1.37
Human activities' affect on Earth systems (#2)	4.28	1.20	5.03	.98	5.15	1.08	5.29	1.00
Use of technology for study of science (#3)	3.34	1.25	4.50	1.12	4.46	1.25	4.95	1.12
Interaction of water, land, air and life (#4)	3.61	1.27	4.52	1.26	5.11	1.08	4.89	1.03
Earth history (#5)	3.13	1.28	3.84	1.32	4.17	1.34	4.43	1.41
Plate tectonics processes (#4)	2.07	1.16	4.03	1.47	3.35	1.49	4.72	1.07
Catastrophic events and their impacts on Earth systems (#4)	3.89	1.25	4.76	1.14	4.96	1.07	4.97	1.06
Evolution (#5)	2.94	1.37	4.80	1.17	3.73	1.45	4.90	1.30
Solar system (#6)	3.20	1.38	4.72	1.27	4.34	1.36	5.06	1.06
Recycling of materials (#2)	2.89	1.15	3.79	1.44	4.06	1.24	4.06	1.35

Table 1 (continued)

Changes of Earth systems through interactions of the subsystem (#4)	3.03	1.10	3.40	1.49	4.02	1.20	4.12	1.41
Cycles in nature (water cycle, rock cycle, etc.) (#5)	3.58	1.08	4.58	1.25	4.89	1.29	4.93	1.17
Rotation of Earth (#6)	2.22	1.19	4.89	1.15	4.44	1.36	4.95	1.05
Motions of Earth and their relationships to the seasons and tidal changes (#6)	3.50	1.31	4.92	1.01	4.69	1.26	5.07	1.05
Careers in science (#7)	3.13	1.28	3.84	1.32	4.06	1.35	4.14	1.44
Ohio's geology (Local geology for Korean subjects)	2.20	1.20	4.17	1.37	3.68	1.38	4.16	1.26
Environmental issues in Columbus (in Bucheon for Korean subjects)	3.20	1.34	4.10	1.54	4.85	1.26	4.52	1.47
1: Scores were measured with a 6-point scale where 1 means no knowledge and 6 means very knowledgeable. 2: Scores were measured with a 6-point scale where 1 means very trivial and 6 means very significant.								

In order to determine any possible reasons why Korean students have lower self-reported knowledge scores about all seventeen concepts and topics related to Earth Systems Education, science content (knowledge section) in Korean National Common Basic Curriculum for middle school students were examined. As can be seen in Table 2, it seemed that Korean middle school students would not have much opportunity to learn about most major concepts and topics related to ESE except for related concepts to ESU#5 and #6 such as structure of Earth, Earth materials, Earth and stars, and Earth's history. Interestingly, even though the Korean national science curriculum covered those concepts and topics, it appears that Korean students have very low self-reported knowledge mean scores for concepts and topics related to ESU#5 and #6. American students who had ESE exhibited higher self-reported knowledge mean scores for all Earth systems and concepts.

Table 2. Science content (knowledge section) in National Common Basic Curriculum for middle school levels in Korea (Ministry of Education, 1997b, p. 30)

Grade	***Knowledge Section***			
	Energy	Matter	Life	Earth
7	• Light • Forces • Waves	• Different state in common materials • Motions of molecules • Changes of state and energy transfer	• Life functions in cells • Systems for digestion and circulation • Systems for respiration and excretion	• Structure of the Earth • Earth materials • Properties and motions of seawater
8	• Motion of objects • Electricity	• Properties in matter • Separating the mixtures	• Systems and functions of the plants • Behavioral responses to stimuli	• Earth and stars • Earth's history
9	• Work and	• Compositions of	• Reproduction	• Water cycle and

	energy • Current in circuits	matter • Changes of properties in matter	• Heredity and biological evolution	weather changes • Motions of the solar system

In contrast, the self-perceived significance of the Earth systems concepts and topics between two country students were significantly different for eight concepts and topics: Value of Earth ($F = 6.181$, $p < .014$), use of technology for study of science ($F = 10.078$, $p < .002$), plate tectonics processes ($F = 51.467$, $p < .000$), evolution, solar system ($F = 15.994$, $p < .000$), rotation of Earth ($F = 7.822$, $p < .006$), motions of Earth and their relationships to the seasons and tidal changes ($F = 5.597$, $p < .019$), and Ohio's geology ($F = 5.902$, $p < .016$). It appears that both students have similar self-perceived significance level related to the other nine concepts and topics. Interestingly, even though Korean students have lower self-reported knowledge about major theme of ESU#1, value of Earth, they felt this topic was more significant than American students.

In addition to exploring both students' perceptions of concepts and topics associated with the Framework of Seven Earth Systems Understandings (ESU), students' self-reported knowledge and perceived significance levels of additional two local topics were examined: Ohio's geology (Local geology for Korean subjects) and Environmental issues in Columbus (in Bucheon City for Korean subjects). As presented in Table 1, two means scores for self-reported knowledge for American students were significantly higher than the mean scores for Korean students. Since units and topics in the ESE curricular are based on many local and global environmental issues, this fact could explain the result of the univariate analysis regarding local topics in favor of American students who had ESE.

4.2. Self-reported knowledge and perceived significance of nine Earth systems and environmental topics

The self-reported knowledge and self-perceived significance mean scores of subjects on Earth systems and environmental topics were compared for the two country groups. The mean score of self-reported knowledge for American students (M = 4.52) is higher than the mean score for Korean students (M = 3.57) and total mean score of both students (M = 4.55). On the contrary, the mean score of self-perceived significance reported by Korean students (M= 4.67) is higher than American students (M = 4.43) and total mean score of both students (M = 4.55). Generally, Korean subjects who have lower self-reported knowledge level perceived the Earth systems and environmental issues to be significant more than the American subjects did.

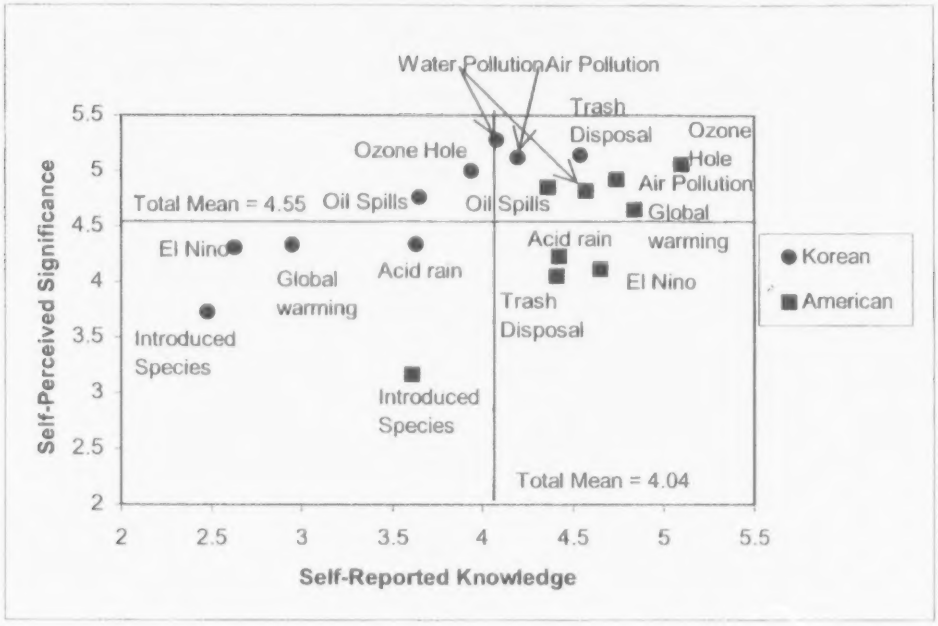

Figure 1. Classification of nine Earth systems and environmental topics by self-reported knowledge and perceived significance mean scores

In relation to students' self-reported knowledge level, the Korean subjects reported themselves most knowledgeable of trash disposal (M = 4.54), air pollution (M = 4.20), and water pollution (M = 4.08). Introduced species (M = 2.48), El Niño (M = 2.63), and global warming (M = 2.95) were perceived to be least familiar by Korean subjects. However, the American subjects reported themselves as most knowledgeable about the ozone hole (M = 5.10), global warming (M = 4.84), air pollution (M = 4.74), and El Niño (M = 4.65) and least knowledgeable about introduced species (M = 3.61).

ANOVAs were used to check for significance differences between the two country groups in self-reported knowledge for the 9 topics. As presented in Table 3, differences for the following eight dependent variables were found to be significant ($p < .025$ or better): Acid rain ($F = 30.966$, $p < .000$), air pollution ($F = 12.997$, $p < .000$), water pollution ($F = 8.689$, $p < .004$), global warming ($F = 126.506$, $p < .000$), introduced species ($F = 9.796$, $p < .002$), oil spills ($F = 16.851$, $p < .000$), ozone hole ($F = 44.863$, $p < .000$), and El Niño ($F = 136.583$, $p < .000$). For eight of the 9 topics (dependent variables), the mean scores for the self-reported knowledge level for American students were significantly higher than those of the Korean students. Interestingly, only the mean score of trash disposal for the Korean students (M= 4.54) was higher than that of for the American students (M= 4.41). But, there is no statistically significant difference between the two mean scores.

Table 3. Results of univariate analysis of variance for self-reported knowledge and perceived significance of the nine topics' mean scores between the two country students.

DV		*SS*	*df*	*MS*	*F*	*p*
Acid Rain	K	34.265 225.735	1 204	34.265 1.107	30.966***	.000
	S	.574 223.096	1 204	.574 1.094	.525	.470
Air Pollution	K	16.238 254.869	1 204	16.238 1.249	12.997***	.000
	S	2.334 143.588	1 204	2.334 .704	3.316	.070
Water Pollution	K	12.751 299.365	1 204	12.751 1.467	8.689***	.004
	S	12.028 171.273	1 204	12.028 .840	14.326***	.000
Global Warming	K	181.891 293.313	1 204	181.891 1.438	126.506***	.000
	S	3.823 253.633	1 204	3.823 1.243	3.075	.081
Introduced Species	K	66.631 380.131	1 204	66.631 1.863	35.758***	.000
	S	17.562 365.701	1 204	17.562 1.793	9.796***	.002
Oil Spills	K	25.865 313.130	1 204	25.865 1.535	16.851***	.000
	S	.330 275.287	1 204	.330 1.349	.245	.622
Ozone Hole	K	67.685 307.772	1 204	67.685 1.509	44.863***	.000
	S	8.4E-02 223.605	1 204	8.4E-02 1.096	.076	.782
Trash Disposal	K	.835 380.490	1 204	.835 1.865	.448	.504
	S	58.284 304.648	1 204	58.284 1.493	39.028***	.000
El Nino	K	201.193 300.502	1 204	201.193 1.473	136.583***	.000
	S	2.179 261.258	1 204	2.179 1.281	1.702	.194

Note. P value corrected by Bonferroni's inequality principle (Klockars & Sax,1986).
***$p < .000$.

With regard to students' self-perceived significance for Earth system and environmental topics, the scores of students' perceived significance will be greater when they think or believe that an environmental problem is more serious, certain, perceivable, and more harmful to their health and well-being (Lee, 2000). From Korean subjects' point of view, the most significant Earth systems and environmental topics were water pollution (M = 5.28), trash disposal (M = 5.14), and air pollution (M = 5.12). The least significant issue was introduced species (M =

3.73). American subjects reported that the most significant ones were ozone hole (M = 5.06), air pollution (M = 4.92), and oil spills (M = 4. 85), whereas introduced species (M = 3.17) and trash disposal (M = 4.05) were reported to be least dangerous (Figure 1).

As represented in Table 3, results of the univariate tests for the self-reported knowledge scores between the two groups indicated that three of the nine dependent variables (environmental topics) were significantly different: Water pollution ($F = 14.326$, $p < .000$), introduced species ($F = 9.796$, $p < .002$), and trash disposal ($F = 39.028$, $p < .000$). Interestingly, Korean students perceived all three environmental topics to be more significant than did the American students. For three of the nine topics, the mean scores of the perceived significant level for the Korean subjects were significantly higher than those of the American subjects.

4.3. Information source about environmental issues

As can be seen in Table 4, the majority of Korean subjects answered that their most frequent source of information on Earth systems and environmental issues was TV: Oil spill (71%), water pollution (65%), and trash disposal (64%). On the contrary, most American subjects responded that their frequent information source on the issues was from their school and class regarding acid rain (90%), endangered species (84.2%), ozone hole (78.2%) and, air pollution (76%) except for oil spills (38% from TV). The notable differences between the Korean and American subjects were observed in most frequent information source on the environmental issues.

Table 4. List of most frequent information source on earth system and environmental issues

	KOREA (110)			USA (102)		
	Item+	Missing Value	%++	Item+	Missing Value	%++
Acid Rain	TV (68)	1	62	School (90)	2	90
Air Pollution	TV (68)	1	62	School (76)	2	76
Water Pollution	TV (71)	1	65	School (73)	3	74
Global Warming	TV (55)	4	52	School (73)	2	73
Introduced Species	TV (46)	4	43	School (61)	1	61
Oil Spills	TV (77)	1	71	TV (38)	3	38
Ozone Hole	TV (58)	1	53	School (79)	1	78
Trash Disposal	TV (70)	1	64	School (71)	2	71
El Niño	TV (61)	3	57	School (59)	3	60

+: 9 information sources are provided: School (Class), Parents, TV, Internet, Newspaper, Books, Magazines, Radio, and Don't know
++: The percentage is excluded missing value

5. CONCLUSION & DISCUSSION

In this exploratory study, dramatic differences between Korean and American subjects were found in self-reported knowledge levels of both major Earth systems

concepts and environmental topics. The findings indicated that the self-reported knowledge levels of Korean subjects were significantly lower than the mean scores of American subjects. Lowest knowledge levels were reported for introduced species, global warming, El Niño and endangered species by Korean subjects. For Earth systems topics Korean students' knowledge was lowest in local natural resources and local geology. Furthermore, Korean students responded that the most frequent information source on all environmental issues are television, whereas American subjects learned or received their information related to the issues from their school and classroom.

The findings make us call Korean science and environmental education into question. Do Korean students have any chance to study those local and global Earth systems topics in school? What is the current state of the national curriculum in Korea for Earth science and environmental education? In Korea, the traditional Earth science is still taught as a collection of facts in separate units of geology, meteorology, astronomy, and oceanography. The formal environmental education for middle school levels in Korea was implemented in 1995. The Ministry of Education (MOE) has offered an "Environment" curriculum that was designated as a separate school subject. Middle school principals can choose "Environment" as an elective subject and schedule it for between 34-68 hours a year (MOE, 1997a). According to Byun (2001), 341 out of the 2741 Korean middle schools (12.5%) chose "Environment" as a subject to be offered at the end of March 2000, and 396 schools (14.5%), as of the end of March 2001. We can assume that more than 85% of middle school students in Korea will not be well informed about their local and global environmental issues if their school principals do not choose "Environment" as a school subject.

Over the past decades, advanced technology and scientific research data (e.g., satellite images) have led to tremendous understandings of planet Earth and to the reinterpretation of emerging environmental issues (Mackenzie, 1998). For example, global climate change, often characterized as "global warming," has become one of the emerging environmental issues of the 21st century worldwide. People are contributing to significant global climate change through our economic and technological activities. Therefore, it is very clear that young students need to know about Earth systems concepts and topics. Recently, a new seventh revised science curriculum has gradually come into effect for all grades (MOE, 1997b). However, the national curriculum does not seem to meet the changing needs of society and educational demands for the global era. Korean science and environmental teachers need different approaches, curricula and instructional methods to effectively teach crucial knowledge for students who will be living out their lives in this new era. An emphasis in science curriculum on ESE and GSL would be a new logical focus with its substantive philosophical groundwork that has been accomplished. The frameworks and ideas of GSL can provide a rationale and basis for organizing all science curricula in Korea.

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CHAPTER 7: THOMAS HUXLEY AND EARTH SYSTEM SCIENCE: OPPORTUNITIES FOR FOSTERING GLOBAL SCIENCE LITERACY IN UK SCHOOLS

Roger Trend, University of Exeter, UK

1. INTRODUCTION

At the heart of the thesis developed in this chapter lies curriculum development in the UK: but which "curriculum" and which aspects of "curriculum" are most pertinent to the definition of global science literacy developed in the first chapter of this volume and Chapter Three in Volume 1? Taking the broadest perspective, I first examine issues surrounding the geography/science interface in UK school education. I then take a strong historical perspective, reviewing two major science education projects separated in time by a century. The two projects have much in common: both aim to develop learners' science literacy across a wide science spectrum; both address curriculum in terms of process and content; both look beyond the formal school curriculum of subject labels; both have implications for UK curriculum development across science (notably at the geography/science interface which has been thoroughly under-exploited in science education planning); and both have much to contribute to the current debate on global science literacy. In particular, both projects go a long way to meet the 5 distinctive criteria suggested by Mayer in Chapter 1 of this volume.

Towards the close of the Twentieth Century, the National Curriculum for England and Wales underwent change, for implementation from September 2000. Despite suggestions from various quarters for radical change in approach, structure and format, these changes were minor. Advocating more fundamental change in the Science National Curriculum, Millar and Osborne (1998) advocated wider use of narrative in teaching. They criticised "an over-concentration on the detailed content of science" (p13) in UK schools and proposed that:

> ... science education should make much greater use of one of the world's most powerful and pervasive ways of communicating ideas - the narrative form - by recognising that its central aim is to present a series of 'explanatory stories'. By this we mean that science has an account to offer in response to such questions as 'How do we catch diseases?', 'How old is the Earth and how did it come to be?', 'How come there is such an inordinate variety of living things here on Earth?' (p. 13).

It is notable that two of the three example questions chosen by the authors relate directly to geological time ("deep time" of McPhee 1981), the major focus taken by the current author in Chapter 13 on Volume One (Trend, 2002). Subsequent illustrations and examples cited by Millar and Osborne include many further references to deep time, including:

- ... gradual evolution of species ...
- ... important and challenging ideas about the huge time-scales over which change occurs ...
- ... the formation and evolution of the Earth ...

- ... the origin of the Universe in a Big Bang ...
- ... evolution of the Universe ... (p. 13/14)

Just as important as the content and process questions raised by Millar and Osborne are those that address the context in which science education occurs. Such questions lead directly to curricular and school-management issues at the geography/science interface (Trend, 1995), questions which are rarely addressed in any depth but which have direct implications for developing children's science literacy in UK schools, especially in the areas of geo-science and environmental science. Since both of the projects selected for examination below link directly to UK school science and geography in the twenty-first century, the next section is devoted to these matters. This is followed by an examination of "physiography", especially Huxley's version, and then of Earth System Science Education. It is clear that curricular decisions in the near future would be well informed by the experiences of these projects, so the concluding sections propose a distinctive approach to Global Science Literacy that arises from these two projects.

2.THE GEOGRAPHY/SCIENCE BOUNDARY IN UK EDUCATION

Children in UK schools engage with science in (upper case S) Science lessons: but they also encounter much science in (upper case G) Geography lessons (and some, of course, in other subject lessons). However, the science in Geography lessons generally passes unacknowledged by all parties, especially the children (Trend, 1991). Geography is deemed to be non-science, just as Science is deemed to be non-geography. Most parties address them as if they were mutually exclusive, despite the obvious and occasionally acknowledged fact that the overlap is sophisticated and open to systematic analysis (e.g. Trend, 1991). Such overlap relates as much to groupings of teachers (sociology) and their idiosyncrasies (psychology) as it does to pedagogy and science curriculum. However, the more visible aspects of the overlap at this science/geography boundary zone relate to content (e.g. earthquakes), process (e.g. fieldwork) and learning materials (e.g. hand lenses). The key proposition in this section is that opportunities for science literacy education within this overlap zone between UK school science and geography remain essentially unexploited.

Despite the inclusion of significant meteorology, geomorphology and geology in UK secondary (11-18 years) school geography courses of the 1990s, the geography/science boundary has remained essentially un-penetrated both by researchers and practitioners. As suggested above, the reasons (not addressed here) are as much sociological, political and psychological as curricular and pedagogical (Trend, 1991; 1992; 1993a; 1993b; 1995). They include perceptions of teachers' territorial rights within school management hierarchies, professional associations with distinct structures and priorities, the structure of the schools inspectorate, initial (pre-service) teacher training arrangements, centrally-funded national curriculum projects (including the National Curriculum itself), teachers' financial and career prospects and the shortage of time and energy for strategic innovative thinking. There remains much scope for cooperation in schools, with or without a national

steer, and such activity would enhance the science literacy of both teachers and learners (Trend, 1996).

The orthodox view of school geography (and of its history) through the Twentieth Century generally ignores its links with science, although occasional mention is made of the "Earth science tradition" (e.g. Marsden, 1995). Some authors examine the opportunities provided through teaching and learning physical geography with a strong scientific orientation (Hilton, 1996). Others warn of the risks of ignoring science/geography links (Walford and Haggett, 1995 p. 10) and occasionally this warning is articulated in more than a few sentences: normally, however, such warnings go unheeded. Thus Richards (1998) expresses

> "some concern that the importance of this *(scientific)* tradition has been, and is being weakened from two directions. It is firstly undervalued by some contemporary intellectual 'turns' in the academic discipline. Secondly .... for some time advisory and inspection procedures in schools have placed geography in a humanities group, with the result that there is a reliance on advisers who, while undoubtedly dedicated, often lack particular interest, expertise and training in scientific approaches. As a result, the opportunity to provide some of the teaching for National Curriculum science attainment targets within geography classes has rarely been considered ..... These trends are at variance with the increasing emphasis in higher education on geography as a discipline requiring the higher levels of funding that characterise the sciences ..." (p. 78)

One of the best indicators of the consensual perspective on school geography is the substantial "Geography Teachers' Handbook", published by the Geographical Association (Bailey and Fox, 1996). It avoids almost completely any mention of science as a school subject, as academic discipline and as a process, despite significant inclusion of natural processes and phenomena such as meteorology, the water cycle and energy transfer in ecosystems. Similarly, geography educators generally deal with the basic concepts and processes of geography at the expense of matters scientific. For example, writing in an influential publication "Geography into the Twenty-First Century", Davidson and Mottershead (1996) identify two aspects of the challenge facing teachers as they prepare to teach National Curriculum tectonic processes, geomorphology, meteorology and ecosystems at Key Stage 3 (ages 11 to 14 years). One concerns the importance of motivation for children. The other refers to the imperative "to ensure that the minimum national guidelines are developed into good physical geography". This wording typifies the current approach to school geography which could be labelled as being "politically correct" since it (understandably) emphasises geographical methodologies to the exclusion of scientific ones, even when the curriculum content requires the understanding and application of scientific concepts. It may also be a professionally sound stance because the authors are committed to school geography rather than to school science: but that is not the point. It is a good example of territorial behaviour, a manifestation of "the territorial imperative" (Ardrey, 1967) fostered so effectively (and possibly inevitably) by the current subject-based structure of the National Curriculum. In short, geography and science are not mutually exclusive (but see Fisher, 1992a), yet opportunities to develop science literacy in the context of geography lessons are almost entirely missed. Thompson (1999) gets to the heart of the matter when he states, "the difference is a matter of perspective and emphasis. In

some areas (*of geography)* e.g. the study of landscape/geomorphology, the methodologies and processes are indistinguishable from those of the physical sciences" (p. 156). In practice, this assertion is certainly true for university (post-18yrs) education, but not for UK school education.

Historically, geological education in Britain has straddled the geography/science divide for well over a century (Trend, 1991), but some authors view this state of affairs with considerable dismay (e.g. Fisher, 1992a; 1992b, 1996). However, the official position of the Earth Science Teachers Association (ESTA) has always been to encourage the teaching of Earth science topics in whichever subject it is taught (Hawley, 1997; Thompson, 1999). This policy reflects the reality of the situation, viz. that school geography and geology have evolved mutual links of many different kinds which have led to the inclusion of significant geological content in the school geography curriculum (Trend, 1991). Connections between geoscience and geography persist in many parts of the former British Empire, as analysed in several chapters in Stow & McCall (1996) (notably South Africa, East Africa, Tanzania, Bangladesh and India) and elsewhere such as Poland (Kryszton and Kryszton, 1996). In Israel it has been suggested that the low status of geology can be attributed in part to its close links with geography, because

> until recently, Earth science topics were only to be found in geography curricula. The geographers have been doing their best to teach the relevant concepts well, but their ability to do so proved to be limited. Without a deep scientific background and with only very limited geological understanding, they have shown that they could not successfully cope with such complex ideas (Orion, 1996, p.21).

The situation in Israel is very similar to that in Britain. Most UK geography teachers are neither educated nor trained to teach science, but many possess the interest and enthusiasm to teach Earth science. It is also the case that many science teachers are neither educated in many aspects of geoscience nor trained to teach them in certain ways: for example, through fieldwork or through investigations and simulations. The point is that geography and science strongly complement each other at the geography/science boundary, but territorial attitudes prevent this from being exploited for educational purposes. It is significant that since 1967 ESTA has felt the need to take an independent line, while courting the sciences more than geography in order to redress a perceived imbalance (Schools Council Geology Curriculum Review Group, 1977). The change of name in 1989 from Association of Teachers of Geology to Earth Sciences Teachers' Association reflected these leanings towards the wider sciences.

The opportunities to foster science literacy by imaginative curriculum development and teaching at the geography/science interface presented by the first UK National Curriculum arrangements in the late 1980s were not taken up. Consequently, all aspects of that boundary remain problematic into the new century. Faced with the dead weight of territorial and professional interests, curriculum planners and funding bodies at all levels have lacked the confidence to be creative and to consider new responses to the politically imposed subject-based curriculum. The research-based proposal for an "Earth Studies" component (Trend, 1991) has not been taken up, although in several countries, notably the USA, the "Earth

Systems" approach is developing apace (Mayer, 1996), funded by central government: see below. Such a failure in the UK could be predicted, of course, since the school subjects of geography and science are so well established as sociological, political and cultural entities. Change at the periphery may lead to loss of status and power and to dilution of the subject's central tenets. In relation to teaching, advisory services, academic input and school inspection, the profession's response to the National Curriculum was, in essence, to look inwards within each of the fortunate (i.e. included) subjects rather than outwards to their conceptual neighbours.

As indicated above, geography teachers normally avoid developing any concept of a "scientific process" in geography lessons, despite ample opportunity to do so (Trend, 1991). In terms of curriculum content, for example, meteorology has been shifted from National Curriculum Geography, to Science, back to Geography and then abandoned entirely from Key Stage 2 (ages 8 to 11 years) for the 2000 revision. Over that period (about a decade), the Science National Curriculum reverted to a biology-chemistry-physics triumvirate (1993-2000 and beyond) after a brief spell as "broad, balanced science" (1989-1993) when there was significant content integration. History confirms that strongly integrated science courses (Nuffield Secondary Science; Schools Council Integrated Science Project) foster the inclusion of significant Earth science content, especially where there is content choice available to the teachers (Trend, 1991; 1995). However, cross-subject approaches to this area of the curriculum have rarely been attempted, despite the fact that much of the content currently called "science" has been taught in the UK under the label of school Geography for over a century.

In short, the geography/science boundary remains unexplored and unexploited for education in science literacy, despite the warming and cooling of the Earth Science Teachers' Association towards the role of geography teachers in geology education. It is a nettle that has not been grasped. Curriculum planners at national, regional (e.g. Local Education Authority) and school levels have focused their attention on a limited range of academic subjects, including Geography and Science, to the exclusion of imaginative collaborative ventures which could serve to enhance children's learning about key global and environmental issues which affect humankind. There are signs that such a tightly-defined subject-based curriculum will change radically in the Twenty-first Century as increased attention and funding are devoted to generic areas such as literacy, numeracy, information and communications technology (ICT), personal social and moral education (PSME) and citizenship. Science Literacy would sit well alongside such counterparts as these, but to date is not seriously on the agenda.

3. PHYSIOGRAPHY

3.1. Context and Evolution

During the second half of the Nineteenth Century a school subject called "Physical Geography" emerged in England, separate and distinct from Geography and the various sciences. It combined aspects of geography and science and was dominated by encyclopaedic and mathematical descriptions of planet Earth and its surface

features, largely in response to the needs of navigation, surveying and exploration. However, the subject didn't last, despite the fact that much of the intellectual debate and practical advancement in geography at the time was led by geologists and others with a broader perspective such as Murchison, Geikie and Huxley "who were among the academic giants of the time" (Marsden, 1986 p. 189).

The publication of the 1886 Keltie Report into the state of UK geography education and the incumbency of Sir Halford Mackinder as Reader in Geography at Oxford University both hastened the decline in the influence of the geologists on school and university geography. Physical Geography disappeared as an "approved school subject" in 1882. After that date, and into the next century, the Geographical Association was becoming influential in developing school Geography as a more holistic, integrated subject, with regional geography and environmental determinism becoming the dominant paradigms (Fleure, 1953; Balchin, 1993). The geologists had had their geographical day (Marsden, 1986), in both school and university contexts. Subsequent developments in school geography over the following decades have barely been touched by those with a geoscience imperative. At the start of the Twentieth Century the time was ripe for curricular realignment in the Earth sciences: parallel circumstances may be discerned at the start of the Twenty-first Century.

One of the most influential, controversial and energetic scientist-educators of the second half of the Nineteenth Century was Thomas Henry Huxley (Desmond, 1994; 1997) whose "Physiography" (Huxley, 1877; 1880) became one of the most popular science school-books of its day (Layton, 1973). Huxley's sister Lizzie called the book a "priceless gem" and his wife Nettie called it "the best of the crop" (Desmond, 1997 p. 102). Stoddard (1975) suggests that it "defined for a generation the way in which the Earth's physical features were studied in Britain" (p. 17), although this is a debatable point, as indicated below. Perhaps it influenced the rhetoric more than the reality. Huxley's "Physiography" grew out of a series of 12 public lectures he gave in London in 1869 and 1870 entitled "Elementary Physical Geography" and "Elements of Physical Science". Huxley

> wanted an all-embracing 'earth knowledge' taught, to keep Britain ahead of Germany. Nothing of its kind was known, so (Huxley) interrupted a hectic schedule to develop a course. ... He launched it at the London Institution, before an enthusiastic audience of boys and masters (Desmond, 1994 p369).

Although his main employment at this time was with the Geological Survey, Huxley was a polymath with diverse interests and background in travel, anatomy, geology and zoology (especially comparative anatomy) (Desmond, 1994; 1997). It is not surprising, therefore, that his physiography (as both a concept and a book) comprises an integration of geography and natural science. However, he was at pains to point out that he

> wished to draw a clear line of demarcation, both as to matter and method, between it *(physiography)* and what is commonly understood by 'Physical Geography' (Huxley, 1880 p. vi).

Huxley was extremely critical of the Physical Geography texts of his day, dismissing them as

> compendia (which) begin at the wrong end, and too often terminate in an *omnium gatherum* of scraps of all sorts of undigested and unconnected information (Huxley, 1880 p. vi).

Clearly, critics of "capes-and-bays geography" are not new! However, courses labelled "physiography" and "physical geography" underwent a degree of convergence during the decades around the turn of the century, despite Huxley's perceptions and the lack of explicit acknowledgment of such a process by various authors. For example, Thornton's "Elementary Physiography" (first published in 1888) covers the basic concepts of geology, meteorology, oceanography and geomorphology and is claimed to be "an elementary introduction to Science" (Thornton, 1896 p. v). Many sources are quoted, including the Challenger reports and works by Geikie (Director of the Geological Survey). Similarly, in his "Physiography for Beginners" (first published in 1896), Simmons covers similar ground, emphasising school practical work, and referring directly to Geikie's work. Like Thornton, he claims to "provide the beginner with (such) an introduction to Physical Science" (Simmons, 1898 p.v). Neither Thornton nor Simmons make reference to physical geography. Somewhat earlier (1877) Geikie first published his "Elementary Lessons in Physical Geography" but even in the revised version of 1884 he makes no mention of physiography, despite the very close content match and Geikie's claim that physical geography "may be regarded as a natural introduction to the teaching of science" (Geikie, 1884 p. vii). However, some authors of school textbooks developed the links between physical geography and physiography, notably in relation to the government syllabuses in the two subjects (e.g. Gregory, 1896). This author also wrote a school text on physiography *per se* (Gregory, 1895) in which he notes the plethora of such publications and attempts to distinguish between physiography, physical geography, geology and science. Thus "physiography is the science of nature. It describes the chief facts and principles of the whole universe. All the sciences may be considered to radiate from physiography." (p. unstated). Gregory also revised Huxley's Physiography (Huxley & Gregory, 1904), nine years after Huxley's death.

It is important to note that the subsequent development of school geography (in its entirety) throughout most of the Twentieth Century does not, in fact, reflect the structure and relationships proposed by Huxley and other physiography authors. Physiography's closest school-based descendants may be found not in geography but in the General Science movement of the first half of the century and in broad balanced science of the last twenty years (e.g. Layton, 1973; 1984; Association for Science Education, 1979; 1989). However, this is in fact a poor match and Huxley's emphasis on real places has been preserved not in these General Science courses but in the physical geography elements of geography courses, often integrated with socio-economic geography. Returning to the issue of the second paragraph of this chapter, no piece of writing exemplifies Millar and Osborne's "narrative" approach to science education better than Huxley's Physiography, as the following section demonstrates.

The brief outline of the main elements of Huxley's "Physiography" is given here in Figure 1 to show its relevance for developing global science literacy in the Twenty-First Century through the effective use of narrative. Figure 1 gives the chapter titles in the Third Edition of Physiography (Huxley, 1880).

Figure 1. Huxley's Physiography in Outline

Chapter	Chapter Title
1	The Thames
2	Springs
3	Rain and dew
4	The crystallisation of water: snow and ice
5	Evaporation
6	The atmosphere
7	The chemical composition of pure water
8	The chemical composition of natural waters
9	The work of rain and rivers
10	Ice and its work
11	The sea and its work
12	Earthquakes and volcanoes
13	Slow movements of the land
14	Living matter and the effects of its activity on the distribution of terrestrial solids, fluids and gases - deposits formed by the remains of plants
15	The formation of land by animal agencies - coral land
16	The formation of land by animal agencies - foraminiferal land
17	The geological structure of the basin of the Thames; and the interpretation of that structure
18	The distribution of land and water
19	The figure of the Earth - construction of maps
20	The movements of the Earth
21	The Sun

Chapter 1 has a strong geographical (spatial) flavour, with the River Thames used as a vehicle for key concepts such as: watershed; basin; valley; tides; direction; Pole Star; and map. As Huxley states in his Preface,

> It was necessary to illustrate my method by a concrete case; and, as a Londoner addressing Londoners, I selected the Thames, and its basin, for my text. But any intelligent teacher will have no difficulty in making use of the river and river basin of the district, in which his own school is situated, for the same purpose (p. viii).

It is notable that one of the major changes made by Gregory (Huxley & Gregory, 1904) was to replace this opening "Thames" chapter with a general "Maps and Mapping" chapter, with consequent removal of that strong sense of place so important in Huxley's pedagogy.

Chapter 2 includes basic geological concepts such as faults and rock texture. Springs provide the spatial context for treatment of London Basin geology. A dozen formations are mentioned, including the Bagshot Sand, London Clay and the Lower London Tertiaries. The emphasis is less on the springs *per se* and more on their geological contexts, especially the chemical and physical properties of the

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rocks. Chapter 2 is much closer to modern school science than it is to modern school geography.

Chapters 3 and 4 combine traditional geography and broad balanced science in equal measure, covering rainfall, clouds, air circulation, mist, fog, dew, snow and ice and meteorological instruments. Modern geography is represented, for example, by a rainfall map of England and Wales and modern science by detailed attention to processes such as saturation, evaporation and condensation. The reader is never far away from the Thames. The stages in the hydrological cycle are set in a clear geological context, starting with rainfall entering rocks (Chapter 3) and ending with the chemistry of Thames water as it enters the North Sea (Chapter 8).

Chapters 5, 6 and 7 sit far more comfortably with modern science than with modern geography, dealing with key scientific processes, but set firmly in a geographical context (viz. Thames Basin). The approach is heuristic in that evidence is first presented and explanations subsequently suggested. A dozen elements and compounds are introduced and the distinction is made between "physical" and "chemical" properties. The last paragraph of Chapter 7 epitomises Huxley's philosophy of children's learning about the physical world:

> And thus we arrive at the last word in science, in its present state, respecting the origin of the river Thames. So far as its flood is pure water, we can trace that water to the ocean. And the pure water which forms the chief component of the sea has certainly been formed, some time or other, by the union of two bodies, oxygen and hydrogen, which, in their free state, are known only in the physical condition of gases (p. 114)

Chapter 8 uses the River Thames (which is "far from being absolutely pure in any part of its course") to introduce the chemistry of natural waters. After all, "absolutely pure water is never found in the economy of nature" (p. 115) so what are these chemicals and what are their sources? Although elements, compounds and chemical reactions figure large, the Thames basin remains the immediate concrete reference.

Chapters 9, 10 and 11 cover surface processes, largely studied in modern school courses as geomorphology in geography. Huxley doesn't miss an opportunity to address basic scientific concepts, but they are set within a sound geographical narrative (cf Millar & Osborne, 1998). Thus, for example, in the account of the fluvial transport of pebbles, Huxley includes the note that

> in estimating the carrying power of running water, it must be borne in mind that the weight of a stone is considerably less in water than in the atmosphere. When a body is immersed in water, it appears to lose a certain proportion of its weight, the proportion depending upon its specific gravity ...(p. 133).

In order to motivate the reader, Huxley provides frequent historical or biographical sketches of the life's work of real people. For example, reference is made to Fahrenheit who was "a native of Dantzic who settled at Amsterdam in the beginning of the last century", to Dr. Plott who "published in the year 1677 a famous work on the Natural History of Oxfordshire" and to "Prof. Agassiz, who ... pointed out the evidence of former ice action in many parts of Britain".

In many ways Chapter 12 on earthquakes and volcanoes is the most poignant for the present thesis because of the tremendous opportunities afforded by such material for developing science literacy. That is how Huxley (and other physiography authors) used these concepts. The irony is that earthquakes and volcanoes figure large in the current Geography National Curriculum but have a considerably lower profile in Science. Huxley describes several earthquakes and volcanic eruptions, referring to specific locations (e.g. Lima and Etna) and addressing natural processes. Rock types, gradual uplift and volcanic structures are included, but the spatial perspective is conspicuous by its absence. The emphasis is on the description of visible processes and products, with very little attention given to possible causes (unusually). Huxley was not writing with the benefit of any theoretical synthesis except a contracting Earth and permanent ocean basins. Even geosynclinal theory had yet to be accepted and the plate tectonics model was yet to emerge. Consequently his account lacks the modern school approaches in which nature, distribution and cause are inextricably linked. Furthermore, Huxley does not focus on volcanoes and earthquakes as hazards requiring risk assessment; this is a modern school perspective which is essentially socio-economic but one which is common in both geography and science courses.

The absence of a unifying plate tectonics theory is even more apparent in the next chapter (13) on "slow movements of the land" because it dwells almost exclusively on vertical movements: "gentle oscillations". The usual evidence is offered, including volcanic swelling at Pozzuoli and isostatic raised beaches in Britain. Folding and faulting are also addressed, briefly, with predictable reference to the London Basin. However, the closest Huxley gets to lateral forces is the hint that "it may be well to mention that contortion and dislocation of strata may be due to squeezing at the sides, and not to the direct operation of forces acting immediately from below" (p. 215).

Chapter 14 deals with basic biological concepts such as cell, protoplasm, nucleus, growth, cellulose, starch, plant, animal and so forth. A discussion of fossils (with reference to the plants of the London Clay) moves to Carboniferous coal. The next chapter (15) moves from the shell banks of the Thames estuary to an examination of coral accumulation, with predictable reference to Darwin's widely publicised theory of coral growth.

From the vantage point of the early Twenty-first Century, Chapter 16 is the most incongruent because it deals almost exclusively with "foraminiferal land" (the Cretaceous chalk lands), a topic entirely excluded from modern school (5-16 years) courses and largely unknown to the modern general public. Huxley devotes 12 pages to these matters, compared, for example, with just a few disconnected sentences on glacial deposition. The first reason for this attention is made clear by Huxley when he refers at length to the (then recent) exploratory voyages of HMS Challenger which produced much new data on ocean basin sediments. Furthermore, the emphasis on vertical earth movements focused attention on evidence which might convince the young learner about such gradual movements: hence soft foraminiferal sediments become uplifted to create new lands of a highly fossiliferous "softish limestone" (p. 271). (However, we now know that chalk comprises largely plates of coccolith algae, i.e. plants, rather than foraminifera – i.e. animal – shells).

The closing five chapters cover matters that are geographically concentric. The first is a straightforward account of the geology of the Thames Basin, with emphasis on the uniformitarian interpretation of evidence rather than landscape description. The second (Chapter 18) moves from the relief features of the London Basin to the continental and global scale. Although it is not an encyclopaedic treatment of the world's relief features (Huxley disapproved of the Physical Geography of his day for this very reason), it contains very little explanation. The reason is clear: there was no unifying model or body of theory that could give a neat and intellectually honest explanation for these features. The "contracting Earth" theory dominated. The plate tectonics model had not been propounded, although it is of interest to note that this chapter contains Huxley's only hint at á possible set of causes related to continental drift. He notes that "the eastern coast of the American continent presents the same sort of rough parallelism with the western coast of the old world ... Where the one is convex, the other is concave, and vice versa". Huxley's omission of any further reference to continental drift is significant because several authors (Abraham Ortelius in the 16th Century, Francis Bacon in the 17th Century and Pelligrini in the 19th Century) had matched coastlines and suggested ancient catastrophic rupture as a cause. Wegener remained unanticipated in his terms.

The third and fourth of the 5 closing chapters deal with an even larger scale: planet Earth. The final chapter first addresses the Sun, then moves logically to (Earth's) ocean tides and ends neatly with a final visit to the River Thames:

> "the spectacle of the ebb and flow of the tide, under London Bridge, from which we started, proves to be a symbol of the working of forces which extend from planet to planet, and from star to star, throughout the universe" (p. 377).

Clearly Huxley brought together geography and science in a way that has not subsequently been achieved on any significant scale, despite the opportunities of organisation and communication afforded by a national framework for curriculum development set up at the end of the 1980s. As many predicted, the National Curriculum Working Groups worked largely in isolation and were subject to pressures from many interest groups. Initially, in 1988, the Science Working Group invited a range of interest groups to each give 45 minutes presentation of their curriculum concerns and priorities. Predictably, the working groups behaved in a strongly territorial fashion and produced overloaded curricula (Thompson, 1998). Again predictably, the Dearing Review of the mid-1990s retained the subject-based structure but reduced the content. The end-of-century review provided a further opportunity to address the geography/science issue but no radical proposals emerged. Perhaps we can learn from Huxley in the Twenty-First Century.

4. EARTH SYSTEM SCIENCE EDUCATION

In response to ongoing debates about improving science education in the USA, the report of Project 2061 (American Association for the Advancement of Science, 1989) has contemplated the integration of a considerable Earth and planetary science

component into school curricula that need to be written for each of the 50 states and many more local school districts. The Earth System Science (ESS) approach is an attempt to produce a new synthesis of the Earth and space sciences (Ireton, Manduca and Mogk, 1996), although it was not conceived for this purpose. It has the potential to provide some solutions to curricular and pedagogic problems that have beset UK education for over a century, notably the place of geology in the school curriculum and the range of issues at the geography/science interface. It explicitly addresses science literacy in the widest possible curricular context. In short, Earth Systems Science Education has the potential to provide a framework for developing science literacy in UK secondary schools, provided that issues at the science/geography boundary are also addressed. This approach is already well-established in UK university undergraduate education, with texts such as Ernst (2000) and Allaby (2000) being widely used in broad-based courses which carry labels such as science, geoscience, Earth science, Earth studies, geography, geology and environmental science/geology/geoscience. It is significant that, within that volume, Kennedy (2000) states that "dressed up in a more modern name, physical geography **is** Earth systems science" (p. 13). Such a blurring of the boundaries is not occurring in schools: hence the problems identified above.

It is proposed that the Earth Systems Science approach has the potential to provide some answers to these problems at the geography/science boundary (identified above) in Britain so that children's science literacy may be enhanced across the curriculum. The ESS is being developed largely in the USA where the Earth science tradition within geography is far less significant than it is in Britain. Furthermore, it is being developed as an approach to science teaching at both undergraduate and school levels (and beyond, in society at large). The dominant perspective among ESS advocates is that it should be all-pervasive within science courses.

Mayer (1996) has suggested an Earth Systems Education Framework for an integrated ESS education in schools (ages 5 to 19). Earth scientists and Earth science educators should

> offer leadership for the development of integrated science curricula at all levels and help curriculum developers to see the logic of planet Earth as the organising focus for such curricula (Mayer, 1996, p183).

The Earth Systems Education Framework is a tool for curriculum planning which ensures the integration of 7 key "Understandings" within school science curricula. These are further subdivided into 36 statements at a lower level (See Appendix A). The seven Understandings of ESS provide an ideal structure for UK school curriculum development which could bring together those aspects of geography, geology and wider science which most contribute to children's education in science literacy. It would not only provide common and, indeed, neutral ground for those science and geography teachers who perceive their subjects territorially but also provide familiar content relationships for those who have passed through university education in recent years, with the emphasis on cross-curricular scientific study of the natural world. In short, we need some trickle-down from universities to schools

in order to remove the geography/science barrier. The resultant curriculum would reflect the best aspects of ESS and Physiography.

Firmly embedded within any UK school science curriculum which matches the ESS and Physiography approaches and which is designed to foster global science literacy must be one of geology's key organising concepts: deep time. The educational potential of this concept is examined in Chapter 13 of *Global Science Literacy* (Trend, 2002) where some research results are examined in the context of the literature.

5. CONCLUSION: FOSTERING SCIENCE LITERACY THROUGH AN EARTH STUDIES CURRICULUM STRUCTURE

Huxley's Physiography and the extant Earth Systems Science have much in common, notably their concern for cohesion in children's learning about the natural world. Both make significant use of narrative in the sense implied by Millar & Osborne (1998) and developed by King in Chapter 4 of *Global Science Literacy* (King, 2002). However, UK secondary school curricula do not readily lend themselves to the cohesive "Earth science" approach for the (largely sociological) reasons noted at the start of this chapter. In particular, geography and science are separated by a significant gulf. Science literacy is addressed by science teachers during science lessons, and often in science laboratories. The idea that children's science literacy should be fostered elsewhere in the curriculum, such as geography, by teachers other than science teachers, is not well-received within and beyond the teaching profession. Such a process would be perceived and labelled as non-specialist teaching, with connotations of inadequate subject knowledge, inexpert teachers and low quality teaching. Indeed, current Initial Teacher Training (ITT) courses place great emphasis on the subject expertise of new entrants to the teaching profession, but it is narrowly-defined and closely matched to the pupils' own National Curriculum content (Department for Education and Employment, 1998). Teachers being trained to teach biology, chemistry or physics at Advanced Level (normally 16-18 years) are required to cover specified content in their chosen subject. There is no equivalent specified content for Advanced Level geology, meteorology or environmental science. Furthermore, there is no ITT National Curriculum for Geography, although new entrants to the profession are required to demonstrate knowledge and understanding at undergraduate level of pupils' curricula (5 to 19 years). As in previous decades, the extent to which geography teachers choose to address matters of science literacy depends on values and priorities at the personal, departmental or school levels (Trend, 1991).

In the UK school context, the approaches used in Physiography and Earth System Science provide pointers for substantial collaboration between science and geography teachers. It has been shown elsewhere (Trend, 1991, 1995, 1996) that such collaboration has the potential to improve children's science literacy in several ways. Within UK secondary (11-19 years) education, schools have the freedom to structure their curricula as they wish, provided they meet the statutory requirements: this is regularly inspected. The curriculum structure for Earth science outlined in the next two paragraphs would have clear advantages for learners, teachers and schools:

1. It would remove the barrier between "Science" and "science", the first referring to a timetabled school subject and the second to the knowledge, skills and understanding which contribute to the development of children's science literacy
2. It would allow schools to capitalise on the particular strengths and preferences of their teaching staff.
3. It would allow the teaching, learning and practising of science literacy in a wider context that goes beyond Science *per se*.
4. It would provide a coherent, cohesive and familiar structure for children, with Planet Earth at the centre.

It is proposed that an **Earth Studies curriculum module** be developed in each secondary school (11-19 years), to sit astride the established subjects of Science and Geography. Such a development would require a steer at national (central government) level, to be provided through the Qualifications and Curriculum Authority, although previous small-scale attempts at such cross-subject coordination have not led to significant innovation (Trend, 1991). One key aim of each school's module would be the development of children's science literacy in terms of process, skills, knowledge and understanding. The content would be broadly similar to that included in both Physiography and Earth System Science and would arise from National Curriculum and nationally-agreed curricula. Elsewhere (Trend, 1991 p. 746) it has been suggested that a four-fold content structure be adopted, corresponding to the hydrosphere/cryosphere, atmosphere, biosphere and geosphere. Within each of these four units would be embedded the skills, techniques, processes, concepts and understandings necessary to further children's science literacy, largely corresponding to the Seven Understandings of Earth System Science (Appendix A). Beyond the curricular concept framework provided by the four spheres and the seven understandings, the Earth Studies module would need to address all the "collaboration facets" (Trend, 1995), which can profitably be used to facilitate Geography/Science coordination. These include not only the highly visible elements of science processes, skills and techniques but also values and attitudes, assessment of children's learning and teachers' personal preferences.

To finish, the development of children's science literacy should not be (and is not) confined to lessons labelled "science". Too much is put at risk if that philosophy prevails and if children are only permitted to learn science if a science teacher is guiding it. Put in this way it is clearly ridiculous: children's understanding of science is enhanced in a wide range of contexts. However, this discussion is not essentially about children's learning: it is about the formal set of structures and processes called schooling, with all that this entails. It is not insignificant that Huxley carried out his teaching in non-school contexts.

Future curriculum planning at UK national, regional and local scales should exploit the distinctive strengths of ESS and Physiography in order to re-structure that part of formal UK secondary (11-18 years) schooling which addresses planet Earth. Many primary (5-11 years) teachers already use this approach, although national Curriculum constraints do not help. Greater integration within an Earth Studies structure (along the lines advocated above) is likely to raise the game of both

teacher and learners, all of them standing on the shoulders of Thomas Henry Huxley who has given us a visionary model for Twenty-First Earth science education.

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CHAPTER 8: THE APPLICATION OF GSL PHILOSOPHY TO SCIENCE EDUCATION IN THE PEOPLE'S REPUBLIC OF CHINA

Jiang Yu, Fitchburg State College, USA

1. INTRODUCTION

Science education has been seen as a major component and force in the process of modernization of China since 1900, when the country's modern education system was established with a strong emphasis on science and technology. In the early years of republic revolution, from 1900 to 1922, the old imperial education, which served an elite class and emphasized the knowledge of Chinese classics and history, was overthrown. Science teaching, spearheaded in a movement that blended Confusianism with Western thought, helped to transform the Chinese concept of education from a means for achieving social harmony and good government to a pragmatic practice for realizing political, social, and economic progress. Its success was not recognized immediately, but nevertheless profound. It introduced a basic concept of modern science to an increasing population of students whose cultural roots had hardly counted scientific and technological knowledge as an element for the enlightenment of being. It thus paved the road for the modern Chinese study of science, and planted seeds for future production of science and engineering professionals in China.

The Sino-Japanese war, which erupted in 1937, World War II, and the Chinese civil war between the Nationalists and the Communists interrupted this initial development of science education. When the communists took over the country in 1949, all levels of schools were reestablished. However, education in general soon took a major change in which the Russian model became dominant. Reforms in curriculum and teaching methods followed a new philosophy of education that accentuated the goal of constructing the socialist society, and individual needs were rendered to the socio-economic commitment of the state. Consequently, science education was emphasized to produce scientific and technological specialists for the society but not to enhance individual interests in the liberal science and enlightenment education. This communist interpretation of education continued until the conflict between ideological oppression and free will of the educated minds culminated and an ultimate clash closed all schools in 1966. This great social turmoil, namely Proletarian Cultural Revolution, stopped all formal education for ten years, including school science teaching.

Since 1977, China has experienced a new social reconstruction as well as a rapid economic development, as the country gradually moves away from the traditional planned economy towards a market economy. All levels of formal education are re-instituted, in which science education is promoted as a central force that stimulates and ensures further economic development and the well being of all citizens. This is an unprecedented era in modern Chinese history, which embraces a capitalist economy under a socialist political structure. The question is: what kind of educational philosophy is required to direct the teaching and learning of science as demanded by the economic reform and social progress?

This chapter will examine some aspects of science education in contemporary China. In particular, the following three questions will be addressed: 1) What problems

and challenges is China faced with in science education? 2) How is science curriculum structured and instructed in the elementary and secondary schools? 3) What changes and improvements are sought and how can GSL philosophy help?

2. PROBLEMS AND CHALLENGES THAT FACE CHINESE SCIENCE EDUCATION

2.1 Population and Economic Challenge

According to the Bureau of Census of the U.S. Department of Commerce (Bureau of Census, 1999), China had 1.25 billion people in 1999, one-fifth of the world population. Of which, about 30 percent were urban residents based on their residency registry, and the remaining resided in the rural area. The pressure of this huge population has created various problems for the society, including many that concern education. For example, after ten years of social and educational turmoil, China's already poor education prevailed and it is today still a lowly educated country with inadequate school systems. In addition, demographic problems such as rapid aging of the population, declining of available manpower, difficulties in population control, rapid urbanization with fast growing migrating masses, rising unemployment, and environmental degradation all interfere with education. Thus, the population-related challenges have become the predominant problems facing China today.

2.1.1 Aging Of Population and Declining of Available Manpower. The burden due to rapid aging of the population and declining of availability of manpower can be, on one hand, reduced if the young generation receives a better overall education to compensate the decline of manpower with an increased labor productivity. But on the other hand, education can be negatively affected because of limited resources and severe shortage of teachers.

Increase of labor productivity depends on skills training as well as educational attainment of the workforce. According to Barro and Lee (1995), the average educational attainment for the Chinese population of fifteen years in age and older only reached six years in 1990. Though the younger generation tends to be better educated than the older, China's demographic trends signify a quick slowdown of education-based improvements in labor productivity. Education, thus, faces a systemic challenge for improving its efficiency in training adults as well as teaching the young. Notably, in the age of technology and for China's determination to industrialize, skills training will require a substantial amount of basic scientific understanding, which can only be made possible with an effective science education to all primary and secondary school students.

Encouragingly, China passed its nine-year compulsory education law in 1986, which is a main factor responsible for having 97 percent of the primary-age children currently attend school (Banister, 1991) and learn subjects including mathematics and science as those who attend schools in the United States and other developed countries. This is a good educational gain, but how effective the school science teaching is and how the shortage of science teachers is solved remain largely of speculations.

2.1.2. Urban Growth, Migrants, and Rising Unemployment. Began in 1979, China's rural economic reform set loose a large surplus labor from the countryside. Its open-door policy also softened its once rigid restrictions on the migration of population from rural to urban areas. Attracted by job opportunities, better incomes, and higher living standards, huge migrating populations formed in cities and towns and eventually became dominantly overwhelming in urban lives.

The migration has benefited urban regions with a fast growing economy, but at the same time it has also caused many problems such as over urbanization and rising unemployment, which in turn produce more problems including considerable demands on the already strained education system. In addition, commonly because of the nature of the mobility of the migrants and their non-existence in the urban registry, migrants' children drop out of schools or attend schools irregularly, which make school administration and management difficult. Although the entire education system is faced with these unprecedented challenges, science education is especially vulnerable because of limited resources, severe shortage of qualified science teachers, and a lack of public understanding or misunderstanding of science education's potential in helping solve social problems.

2.1.3. Population Control. The aging of the population in China is partially a result of the country's policy on population control, which was first introduced in 1970 as a popular campaign and later developed into a state mandated one-child-family-policy in 1979. The idea of population control was to curtail the rapid population growth, because by 1970 China's population already increased to 830 million from 1953's 588 million (Morrish, 1994), and the pressure of over population had begun to emerge. The one-child-family-policy was thus "implemented in response to concerns about the social and economic consequences of continued rapid population growth", and since its implementation it has helped in reducing at least 250 million people, compared to that if such control was never used (Kane and Choi, 1999).

The implementation of the one-child-family-policy before 1982 was rather rigorous in cities as well as in the countryside. However, as the migrant population grows bigger in the social and economic reforms, it becomes more difficult. Statistically, the campaign for population control is more fruitful in cities and the implementation of the strict policy is more successful in the urban areas than in the rural regions. Two of the major reasons are believed to be the higher average levels of education among city residents and the security of urban jobs. Better education enables people to foresee population-related problems at large scopes as well as at the personal level, and thus they voluntarily join the call for control. As for the security of jobs, it is easier to encourage people to follow the policy with job-related incentives such as increased benefits and better pay, which are not available options to peasants on the farmland.

Since the economic development will most likely sustain the sizable migrant population and further change the structure of job market from the state employment to that of private enterprises, China will have to pursue its goal for population control through education and betterment of lives. Here, science education is crucial, since a

basic understanding of the importance of a balanced relationship between man and nature can only be established on a scientific basis. In addition, health care, hygiene, birth control, and the care for the young as well as the elderly all practically depend on a basic understanding of modern science.

2.1.4. Environmental Degradation. The rapid economic growth and over urbanization, in addition to the huge population, have caused serious problems of environmental degradation. Water, air, and noise pollution are unmistakably evident, as sanitation facilities are inadequate, water resources per capita ranks 88th in the world (Gu, 1995), and 90 percent of the Chinese cities do not even meet the already inadequate local standards for air quality (Urbanowicz, 1999).

The mounting environmental problems are often indifferently blamed on economic growth and over population. However, factors such as abuse and unwise use of the available natural resources, short-term utilitarian attitude of people (especially of those migrants) towards materials and environment, disinclination of both heavy and light industries on pollution-control programs, ill energy consumption, and increased emission of carbon dioxide must be treated before the problems can be ultimately diminished. While this requires enforcement of environmental laws, improving science and environmental education programs is even more fundamental.

Fortunately, Chinese leadership has gradually acquired a general understanding of this, and in recent years "environmental protection and sustainable development have been adopted as part of the national development strategy. . . Science, technology, and education have been identified as the tools to help the world's largest developing country to attain prosperity. And the public is becoming increasingly aware of environmental problems and getting more involved in the decision-making process" (Wu, 1999). What is needed is an effective science education system that enables effective teaching of science literacy, the understanding of the balance between man and nature, and the attitudes and techniques that make such balance possible.

2.1.5. Economic Growth. Most of the problems mentioned above, e.g., over urbanization, rising unemployment, and environmental degradation, are direct results of the economic reform that began in 1978. The success of the reform is obviously evidenced in China's breathtaking economic growth. Its expanding market economy has spurred its average gross domestic product per capita to an annual rate of 7.5 percent (McNatt and Oleck, 2000). This is remarkable in terms of economic development, which is aimed to raise the standard of living of Chinese people. But, if the problems caused by this fast economic expansion, especially the degradation of environment, remain unsolved, the quality of life will inevitably slip down as well as the continuation of the expansion itself will be unavoidably hindered. For example, China already faced an imbalance between demand and supply for grain for the first time in 1994, which resulted in the worst inflation of 24 percent in the history of communist China (Brown, 1997). Dropping water tables everywhere is another threat. Farmers are forced either to drill deeper wells or to abandon irrigated agriculture. Flooding and other natural disasters have also increased both in frequency and degree

of damage. The list can go on and on, and passive fixes may be many. But, the ultimate relief of the problems relies undoubtedly on education, especially effective science education for all citizens.

2.2. Struggle for Democracy and Social Justice

Democracy is not an indigenous idea of China. It was introduced to it, together with science studies, only in the beginning of the 1900s. Before that, feudal dynasties ruled the country for more than two thousand years in which autocratic imperial power and authoritarian civic system were built upon the Confucius and Mencius ideology of government by a hierarchical social structure. Unlike citizens in a democratic society, ordinary Chinese people were not allowed to be involved in politics, nor had they any rights in participating in political decision-making. They were expected to be obedient and respectful to their rulers as the rulers were expected to use state power to protect and nourish them.

The authoritarian system worked well for the closed society. Although there were repeated rebellions throughout history when rapacious officials or onerous taxes made living conditions intolerable, social unrests only brought down one dynasty for another (hoped to be better) dynasty while the absolute supremacy of the authoritarianism was never challenged in ideology and philosophy. Until the 19th century, when China was defeated by western powers with modern weaponry, the confidence in Qing government (China's last imperial dynasty) was gradually lost and mass rebellions against its rule eventually caused its final fate. Different from past revolutions, the superior modern machinery of the West faltered the Chinese sense of security and greatness of their political system as well as demonstrated the power of science. It was then China's intellectuals turned to the West and imported two new concepts: Democracy and Science.

Thus, democracy and science from the very beginning were a pair of inseparable twins in a Chinese sense. They were both taught in the new schools that were established in 1905, as well as promoted and popularized in social movements such as the May 4th movement. Although the pro-democracy activists had always wanted to move the country towards democratic politics and government, and they actually founded the Republic of China in 1911, the cultural tradition and the low levels of education among the majority of the population had worked against it.

In 1949 the communist government unified the country after more than one-half a century's foreign invasion and domestic warfare. This was the beginning of the People's Republic of China. People, educated or uneducated, took a strong belief in the "proletarian democracy". However, with over 80 percent of the population illiterate (Orleans, 1960) and a totalitarian dictatorship knowingly using the authoritarian tradition to maintain its power, democracy remained a fancy word without real meaning in the actual lives of Chinese. Before 1977, "democracy" belonged only to the monologue of the communist government. Science teaching was a suspected child who was searched frequently from inside out to make sure the knowledge only functioned as a tool to serve the state rule but not used on a liberal basis to question the regime's legitimacy. Repeatedly, intellectuals were punished for "bourgeoisie thoughts" and

eventually all individuals with secondary or higher education were classed for distrust and subject to punishment for their educated minds.

This dictatorship brought China severe political, economic, and educational poverty that at one end impeded the hope for democracy but at the other end intensified the cry for it, especially among intellectuals and the educated. Since 1978, when the general population's demand for political reform as well as social justice became life and death, the struggles for democracy and human rights have become inevitably persistent and realistic, especially when the twenty years of economic reform have moved China towards prosperity and opened the eyes of people for a higher standard of living. For instance, while students made almost another May 4th movement in Beijing in 1989 to attack the political ideology on philosophical grounds, peasants quietly began elections of their village leaders on forums of how to manage local businesses and community affairs.

But beyond political and economic climates, what kind of democracy and how to achieve it depends not just upon cultural tradition but also ultimately on the level of education of the general population. In China, it has always been a question among intellectuals and students whether or not to give votes to peasants, for the same reasons that were debated in Europe and the Americas in the 19th century. This question is well founded, because although the illiterate peasants seem to embrace the idea of democracy, their cultural tradition towards politics and authorities is of little true democracy. A transformation of culture for a new democratic one is required. Yet, studies show that grassroots village elections do not induce such cultural change and all the support for such changes is only derived from education (Shi, 2000). Nonetheless, education in China is poor and inadequate, with 22 percent of the population illiterate (Asian Connection, 1998) and no more than 60 percent of its 1.25 billion people able to read books with a good understanding (Zhang, 2000), a democratic rule for human rights and social justice can only remain close to a slogan.

Hopefully the Chinese government in recent years has adopted a policy of "revitalizing China through science and education". The legislature also enacted six education laws between 1980 and 1998 to regulate and govern the educational reform and development (Law, 1999). Science education, as when it was introduced to China a little more than a century ago, faces the old challenge of a massive population and a new exciting objective: teach the people about the real meanings and bearings of democracy through a globally based science literacy.

2.3. Enthusiasm for Internationalization and Global Thinking

China's current economic reform that began in the late 1970s is specifically targeted at the "four modernizations," namely, the modernization of agriculture, industry, science and technology, and defense. Modernization means world class of the state of art. And, history has made it clear that such objectives would be difficult to achieve if the country remained in isolation from the world. Thus, China has operated on an open-door policy for the past two decades, which has enabled gradual economic, technological, and cultural exchanges on the international ground.

The open-door policy has so far generated China a booming market economy. It thus has helped to reduce its population living below the poverty line to only 9 percent (Mann, 2000), put 97 percent of its primary-age children in school (Banister, 1991), and allowed about 320 thousand college and graduate students to study abroad (People's Daily, 2000). During the same period, foreign investment in China has been growing, as international companies and information transfers expand their business into the Chinese market. With these exchanges and developments in the past two decades, China has integrated itself into the global economy and will be, as Singapore's senior minister, Lee Kuan Yew, predicated, "one of the most important players in the global exchange of goods, services, capital, talent and ideas in the 21st century." (Xinhua News Agency, 2000b)

A global economy requires a global understanding of the world as an integrated community of multi-cultures. Such an understanding can only be reached through processes of internationalization with the knowledge of world environments, including the humanistic environment as well as the physical earth environment. To attain a good understanding of world environments, science literacy with a global perspective is essential and necessary, because it transcends all cultures and enables effective communication between peoples.

In summary, an effective science education with a global perspective is urgently needed in China. It will support Chinese people in their efforts to achieve science literacy and enable them to view the world with global understanding. It will stimulate further economic development as well as enable and direct China's social reforms. It will help ensure China's progress towards economic globalization as well as its active role in sustaining the earth's resources and maintaining good lives for its inhabitants. Such a program requires a committed educational system as well as the devotion of science educators working together to solve the problems it faces.

3. CHINA'S SCIENCE EDUCATION IN THE PRIMARY AND SECONDARY SCHOOLS

3.1. General Education System

China's educational system has not undergone substantial revisions since late 1970s in either of its structural or philosophical foundations. Until the early 1990s, all schools were state owned and operated. In recent years, there are private schools established in major cities, but their proportion to state schools is still too small to significantly reshape China's current educational philosophy and system structure (Smith, 2000).

The state-owned educational system provides six years of primary, three years of junior secondary, three years of senior secondary, and four to five years of undergraduate college or university education. China's Compulsory Education Law requires all school-age children attend and complete nine years of elementary and junior secondary schooling. Graduates of the junior secondary schools have the option not to attend senior secondary schools, but those who wish to attain post-secondary education usually complete all twelve years of pre-college studies. All students who wish to attend colleges or universities must also take the National College Entrance

Examinations, which are administered once a year in July, and be accepted to higher education institutes based on their performances on the exams.

At the primary and secondary levels, there are nearly 140 million children attending primary schools, over 50 million attending junior secondary schools, and less than 9 million attending senior secondary schools (Guan, 1999). Typical school ages are: 6 to 7 begin in the primary, 12 to 13 proceed to the first year junior secondary (grade 7), and 15 to 16 continue to the senior secondary (grades 10 - 12) schools.

There are about nine million teachers in China, including nearly six million for the primary, three million for the junior secondary, and about one-half million for the senior secondary schools (Guan, 1999). Typical teachers are trained at three different levels before service: (1) secondary normal schools of three years that lead to the certification for teaching primary schools, (2) normal colleges of two to three years which lead to the certification for teaching junior secondary schools, and (3) four-year normal colleges and universities which lead to bachelor's degrees for teaching senior secondary schools (Pikcunas, 1990).

The country's education system is regulated according to the policies and laws made at the national level. Procedures including educational standards, curriculum, textbooks and materials, student evaluation and the national college entrance examinations, teacher training standards and certification, school accreditation, and degree authorization and recognition, etc. are all determined at this level. The provincial governments have no decision-making rights on these regulations but are responsible for developing, supervising, and administering the actual operations of primary and secondary schools, as well as providing partial funding for them.

The primary and secondary schools typically begin each academic year in September and end the year in July. Semester format is the standard, with each semester lasting four to five months and a winter break in between (customarily scheduled around the Chinese New Year in January or February). Classes are usually run for 30 to 50 minutes in duration, five to six hours a day, and five days a week (Wang, et al., 1996). Teacher-student ratio varies from school to school and depends on subjects and grades, from 1:20 to 1:50 (Chinese Education & Society, 1994).

3.2. School Science Curriculum

Although the Education Commission of the central government determines the primary and secondary school curricula and standards, the education bureaus of provinces or municipalities determine the actual course offerings and instruction for their own districts. Thus, some variations in curriculum design exist from province to province to reflect local economic and demographic conditions.

A popular school curriculum for grades 1 through 9, based on what is used in Zhejiang Province (Chinese Education & Society, 1994), includes a General Course in which students study the connections between people and the physical world and thus aims at nurturing student feelings, ideas, and appreciation of nature and the study of it. Its objective is to "ensure that they [students] grasp the most rudimentary general knowledge of nature and society, and have the fundamental faculties for making observations and for cognitive thinking".

Another course, Life Science & Labor, on the other hand, "ensures that students have the basic abilities to take care of themselves in their everyday lives". It thus aims at helping students to acquire general knowledge about common diseases and illnesses, as well as human medical care. It also teaches them about the use of common household instruments, "so they can actively and enthusiastically take part in projects of labor that contribute to the public good in so far as their abilities actually permit".

At grades 7 to 9, the curriculum breaks science studies into two sub-categories: science and technology. Natural Sciences include physics, chemistry, cartography, computer science, microbiology, environmental protection, energy resources exploration and development, astronomy and meteorology, oceanography and marine studies, animal and plant resources survey, and mineral resources survey. The objective of these courses is to develop student "rudimentary understanding of the human beings and of the natural environment". Students are required to learn the most basic concepts, theorems, and laws of natural sciences and their applications. They are also required to grasp the fundamental means and skills of making observations and conducting scientific experiments, and thus develop scientific thinking skills.

How these natural science courses are organized and arranged for instruction is left to local school systems to determine. Typically, they are structured by disciplines. Students normally take two years of biology at the 7th and 8th grades, two years of physics at the 8th and 9th, and one year of chemistry at the 9th. They are also required of at least one year of environmental protection in their junior secondary experience. Other course offerings vary from school to school. Students at grade 9 can also take one or two of the advanced science courses as free electives.

Industrial, Agricultural, or Vocational Technologies include metalworking, electrical work, domestic electrical appliances, rural plumbing and electrical work, food processing, forest building, vegetable farming, mushroom cultivation, orchard cultivation, farm implements, soil care and fertilizer, crop management, domestic livestock, bee keeping, aquatic products breeding, silkworm breeding, woodworking and carpentry, painting, weaving, pottery, handicraft arts, first aid and nursing, Chinese herbal medicine, and other less science-related tech courses. All these courses emphasize student knowledge and understanding of technologies applied in agricultural, industrial, and service industrial fields. Their objective is to "ensure that students have a grasp of basic knowledge and skills for coping with modern-day life and with productive labor in the modern world." At grade 9, students can opt to take more technology courses as electives based on their interests.

Since attending senior secondary schools is not mandatory, those who do go through grades 10 through 12 are usually college-bound students. Admission to good or key senior secondary schools is very competitive, and the curriculum usually stresses academic subjects and college preparation. Typically, students will take a set of school designed examinations at the end of grade 11, and their scores will be used to determine which academic tracks, usually either science or social studies, to follow for college preparation.

According to Wang, et al. (1996), students who are on the track for natural sciences typically take two years of general biology at grades 10 and 11 studying evolution theory, heredity, and nutrition. They take three full years of chemistry

working on both inorganic and organic foundations. And, they also take three years of physics learning topics from Newtonian mechanics to atomic physics. Both chemistry and physics are test subjects in the National College Entrance Examinations for those who wish to be recruited as science and engineering majors at the higher educational levels.

3.3. Characteristics of Science Teaching and Learning

The influence of China's rich cultural background and the country's strong political atmosphere results in a unique set of beneficial, yet at the same time troubling characteristics in school science teaching and learning. Although in recent years science curriculum reformers and educators try to make changes, the established methods used in classrooms remain outweighing (Gao, 1998).

3.3.1. Cultural and Political Influence of School Science Education. Since Confucius time, China has been governed by an aristocracy of merit, in which scholar-officials succeeded and secured their state posts not by birth but by their performance on the national Civil Service Examinations (Rozman, Sato, & Segal, 1992), for they proved themselves as purified beings who could serve as moral leaders, knowledge fountains, rectified hearts and minds for good government. These scholar-officials were ensured of special status of political power, social respect, and financial wealth. Today, this traditional view of education is retained in the soul of intellectual development in China. Education and schooling is basically regarded as a means for personal perfection and advancement for higher social status or positions. Furthermore, the government promotes the idea of science education especially for training socialist experts who will provide "lofty ideas, moral integrity, a good education and a strong sense of discipline" in the modernization of China.

Thus, culturally the aim of school science is to produce socialist "sages" with expertise in science and technology. This implies an emphasis on the theoretical studies of existing principles, but not on experimentation, discovery, creativity, or challenges to the accepted explanations. In practice, the Civil Service Examinations were abolished in 1905, but Chinese schools at all levels have never truly diverged from the test-driven tradition. At the present, China maintains its academic standards for all levels mainly through regular paper-pencil tests and the ultimate National College Entrance Examinations (Taiwan similarly maintains uniform standards through a system of a standardized national testing service and a national college admission committee.). The result of the above is a school science teaching centered at and organized for tests (Gao, 1998), the same as that "sage preparation" process. Textbook knowledge, which represents the accepted intelligence, is emphasized over experimental or practical training (Su and Su, 1994). Students must not challenge teachers who stand for accomplished wisdom (Wang, et al., 1996). Lectures, recitations, paper-pencil homework problems, and memorization are seen as the standard means of formal education.

Philosophically, at the same time, Chinese have developed an earthling world view over thousands of years, in which people are seen as one part of the natural world

and their understanding of nature is a holistic one. Along this line, modern science is still foreign to most Chinese and its disciplinary methods of studying nature is seen as "unusual" and over simplified. Thus, the importance of modern science in the ordinary lives is taken much less than that in the West. It is a school subject that concerns less in people's being, or understanding of the world. This philosophical view of "western science" also results in an over weight of textbooks, lectures, paper-pencil problem-solving tasks, and rote learning.

3.3.2. School Science Teaching Under the above discussed influence of tradition, culture, and politics, Chinese school science teaching is distinctive in four aspects: collective teaching preparation, teacher-centered classroom presentation, deductive method of lecturing, and emphasis of theories.

1. Teachers at all levels prepare their lessons for classes collectively. This is because individual teachers do not have decision-making right in selecting textbooks and teaching materials, which instead are selected by the national Education Committee. The rationale behind the group preparation is to further eliminate individual differences in presenting and using the materials, and at the same time enable junior teachers to learn from senior teachers' experiences.
2. Science classrooms in China are invariably teacher-centered. Lecture is the standard method of instruction during which students are passive receivers with few chances to raise questions. Teachers are usually very formal (humor in classrooms is seen as a bad behavior and non-professional) and they tend to portray themselves as unquestionable authorities. Demonstrations and student discussions are seldom. Teachers often encourage students to accept the commonly established laws and to practice problem-solving procedures with assigned examples and problems.
3. Lectures of science classes in China are dominantly conducted by the method of deductive reasoning. Normally, a teacher begins a lesson by presenting a theory from the textbook, it is followed with a few specific examples demonstrating the theory, and then students are assigned homework problems similar to those that have been thoroughly worked out on the board. The instruction contains neither much chance for students to ask questions or to engage in discussions, nor does it encourage thought processes that relate the theory with realities of the students' familiar life environments and their personal experience.
4. Lastly, science teaching in China always emphasizes theory more than application. Laboratory exercises are very seldom, hands-on classroom activities, outdoor trips, and field projects are almost non-existent. Paper-pencil exercises over lectured theories are the dominant methods of measuring student achievement.

3.3.3. School Science Learning. Student learning of science, like teaching, also reflects the society's traditional, cultural, economic, and political expectations. Socially, science professionals are guaranteed lifelong employment and placed in positions that bring respect and comfort. Philosophically, mastering of science subjects does not

necessarily mean any change in student's world-views or they will apply such subjects in his or her actual life. Educationally, it is believed that everyone is able to learn science subjects if he/she studies textbook materials industrially enough. And economically, science, like any other subject, can be learned straight out of textbooks with minimal life experience, including experimentation and direct observation. Thus, families and society hold high expectations of children and pressure them to follow their teachers' lectures with minimal educational expense. Because the ultimate goal is to succeed in examinations and to be accepted to the next level of school, students learn science predominantly by memorization and repetitive practice of textbook problems (Gao, 1998).

School science learning in China is a very individual activity. Since classes do not provide many opportunities for either peer discussion or hands-on experience, individual learning is passive in listening, note taking, textbook reading, and homework-problem drilling. Further, since understanding is evaluated mainly by tests, students' focus of study is typically at examination preparations (Su and Su, 1994).

Science students, like those in other subjects, usually do not engage in communications or interactions with their teachers. This is in part physically due to the fact that classrooms and teachers' offices are not arranged in ways to encourage such interactions. Culturally, the tradition also tends to draw a sharp line between students and their teachers. Also practically, learning is an individual activity and students tend to become introverts even among themselves.

4. GSL PHILOSOPHY AND SCIENCE EDUCATION REFORM IN CHINA

4.1. The Potential of GSL for Chinese Reform in Science Education

China's economic development and rapid social reconstruction in the past twenty years have increasingly demanded reforms in education. As a result, in 1982, the Twelfth Congress of the CCP first placed science and technology among the top three priorities in the country's strategic plan for development. In 1986, the National People's Congress (NPC) enacted the Law of Compulsory Education. By 1988, 97 percent of school-age children were enrolled in primary schools and 66 percent of the rural regions that had reached the standard of primary education were accredited to expand to junior secondary education (Li, 1989). Today, the strategy of revitalizing China through science and education remains a major component in the country's tenth five-year plan for 2001 to 2005, which is supported with steadily increased budgets from the central government on science and education (Xinhua News Agency, 2000a).

The call for science education reform has resulted in many provincial and municipal plans for systemic reforms. Though these plans vary from province to province because of regional or local situations, they all respond to the demographic, regional and national economic, social, and political drives discussed earlier in this chapter. Furthermore, these reform plans share a set of similar goals and objectives, and they all bear a common theme emphasizing a systematic design and holistic approach. Below is an example of the ideas and philosophies sought by Shanghai Municipality, a

leader in educational reform in China, for guiding its reform of the primary and secondary school curriculum and teaching materials (Wang, 1994):

a. "The reform of the curriculum and teaching materials must be guided by the ideology of serving the interests of economic and social development";
b. The curriculum must support the theme of "holistic thought, a systematic design, and an overall plan";
c. The teachings must establish not just a strong foundation of knowledge, ability, skills, and intelligence, but also more importantly a foundation for worldviews and philosophies of life, good moral and ethical qualities;
d. The curriculum must help develop a sense of stability and continuity inherent in basic theories of nature and basic skills and abilities for broadly applying or adapting the fundamental theories;
e. The curriculum must enable students to connect theory to reality by stressing the integration of fundamentals and applications, as well as skills to function in society.
f. The reform must be gradually popularized and broadened on the basis of scientific experimentation.

These ideas for reform are supported by the GSL philosophy and objectives. As discussed in the first chapter of this book, GSL's two main philosophical views are that (1) science's primary role for human beings is to conceptually understand and aesthetically appreciate the natural systems of the earth and its surroundings and (2) human beings are products of the earth system and therefore it is our undeniable responsibility to sustain the natural resources and the balance between man and nature. Thus, the GSL philosophy promotes science education for the primary and secondary levels by objectives that aim at (1) achieving conceptual understanding of science studies rather than pragmatism of technology-driven inquiries; (2) developing systematic methodology of science conduct rather than just the reduction approach of traditional science programs; (3) expanding the world views that emphasize the harmony in interactions between subsystems of nature, including that of between the human and other earth systems, and (4) improving the capability of communication between peoples through science studies. In addition, for curriculum development GSL supports the idea that science education must serve the needs of the world as well as that of a nation, and promotes a conceptually organized curriculum that maintains the continuity inherently among various science studies. Compare the ideas sought in the Chinese reform with the philosophy and objectives of GSL; it is clear that GSL has the potential to be an effective guiding principle.

4.2. Appraisal of Chinese School Science Curriculum Based on GSL

4.2.1. Aims and Organizations of the Current Curriculum. The current school curriculum at the primary level tries to blend science into a whole learning concept with other knowledge bodies so that children can make connections of scientific conceptions to the world around them, including both physical environment and humanistic surroundings. This is a good design according to GSL. First, science study is a part of

human endeavor for understanding our world on Earth and beyond. Second, scientific understanding does not arrive alone as an isolated knowledge but rather it intertwines with our whole life experience. The elementary course, General Knowledge, is intended to lead students to "come to comprehend their environmental surroundings, and begin in a rudimentary way to understand the world around them... [and to] develop their ability and interest in knowing." (Zhejiang Jiaoxue Jihua, 1992) If taught with appropriate methods that are consistent with the GSL philosophy, this design could broaden the means of knowing beyond reductionism, and at the same time, incorporate human values as well as the understanding of human beings as interweaving elements in the world system. It therefore could nurture the students in the development of "ideas and feelings of having a fervent love for their homes and homelands, ... as well as for nature and the sciences."

The strength of the curriculum, at this level, is also illustrated in the design of a more practice-based course, Life Science and Labor. This is a first course for students to develop practical knowledge of natural diseases and modern medical care, domestic chores and simple farming or manufacturing labor activities, and common apparatus or machines. Thus, if taught appropriately with methods recognized by GSL, they could be ensured to "develop, in a rudimentary way, simple and frugal living habits and a good healthy attitude toward work and labor", and the appreciation of modern sustainable technology that is developed based on science studies as well as the earth's resources.

The curriculum at the junior secondary level also divides into two areas of study: 1) natural sciences and 2) agricultural, industrial, vocational technologies and domestic life skills. Natural Sciences, which aims at helping students to "learn the most basic concepts, theorems, and laws of natural sciences and the rudimentary application" of them, puts an emphasis on developing a fundamental "understanding of human beings and of the natural environment". This design reflects the Chinese belief that human beings are part of the earth and therefore, they will have to always seek balance between themselves and the earth. This is a good attitude according to the GSL philosophy, since human beings are deciphers of natural laws, but since they are part of nature themselves they must be responsible for sustaining and safe-guarding the physical environment of the earth. Again, if taught with GSL approaches, this curriculum could help achieve "the cultivation of a love and affinity for nature, a spirit of exploration and creativity, and the ability on the part of students to apply their knowledge to analyzing and resolving problems" (Zhejiang Jiaoxue Jihua, 1992).

The major shortcoming of the design for "Natural Sciences" is that it breaks science into disciplinary courses such as physics, chemistry, and microbiology from the 7th grade on, rather than organizing them in a synthetic study of the earth system. According to GSL, a unified conceptual organization of science subjects makes more sense to students at this learning stage for forming systematic understanding of the physical earth that is the primary subject of all science investigations. The disciplinary organization of science studies at this level cuts loose the connections between topics and thus lacks completeness and integrity, which hinders student development of good understanding. Furthermore, since no student is practically able to take all disciplinary

courses in a period of three years, their knowledge base thus will be too fragmented to make them scientifically functional citizens.

The technology/skills training at the junior secondary level continues the practical education that begins with the course of Life Science and Labor at elementary schools. Like Natural Sciences, it breaks into many sub-courses of vocational and career subjects such as metalworking, forest building, and soil care and fertilizer. The design of the curricula addresses the need of technologies for life. Thus, they enhance the theory-stressed science courses. One common theme that runs through all these courses is the emphasis for students to further develop "good labor habits" and understand the relationships among family members, between family and society, and between the human society and the earth. This is good according to GSL, because a scientifically functional citizen must recognize the unique quality of science, its ability to better lives, and its function as a linkage between societies, countries, and peoples. If correctly taught, this can enhance the 7th earth systems understanding in relation to careers and avocations.

The science curriculum at the senior secondary level, on the other hand, is intensive, competitive, examination-driven, and discipline organized. The design of the courses is very similar to that of the Advanced Placement courses offered in US high schools. Because most students at this level are voluntary learners with high motivation, academic qualification, and good self-discipline, the curriculum serves them well in developing further understanding and reasoning abilities and hence prepares them well for future academic studies in colleges and universities. However, according to GSL, the curriculum lacks integration among subjects. Thus, continued from the junior secondary curriculum, it further fragments student knowledge base for achieving science literacy, which requires a systematic understanding of the earth and its surroundings.

More importantly, only 10 to 30 percent of the junior secondary graduates go on to attain senior secondary education, and their central goal is to prepare for the National College Entrance Examinations but not for liberal or vocational purposes. Thus, a larger population beyond the junior level is not currently served by the system. The result is that millions of junior secondary school graduates neither attain college education nor are prepared adequately for work or life. In fact, how many students are driven away by the current college-aimed senior secondary curriculum from seeking further education is not known. Apparently, if China truly wants to expand the compulsory education to 12 years and prepare scientifically functional citizens, the current science education, along with the entire school system, will have to develop and offer non-college-bound tracks or curricula to attract more young people to attend schools beyond the mandatory nine years of schooling.

Overall, the current science curriculum from elementary to lower secondary level is designed for achieving science literacy. But it is cut short at the upper secondary level to shift to specialization when student development of science literacy is not quite completed. With China's desire to modernize and to raise economic levels, there will be a need for realizing the 12-year-compulsory education as well as helping all secondary school graduates to become scientifically literate. Thus, the design of secondary science curriculum will need to change toward the GSL objectives.

4.2.2. Teaching Materials. The current school science teaching materials for all levels are narrow in content and allow little diversity. Commonly, textbooks "tend to be divorced from the realities of the great expanse of rural China or the countryside, and from the special regional characteristics of each area of the country and the characteristics of the various minority nationalities" (Wang, 1994). Materials used for junior secondary sciences lack completeness and integrity, e.g., little consideration of Geography and Earth Science is given. Different teaching materials for both junior and senior secondary courses, though selected and approved by the national Education Committee, are deficient of continuity of knowledge and suffer from insufficient coordination among disciplines. Thus, repetitive coverage or disconnections of content are not uncommon. At the senior secondary level, textbooks give too much consideration to the preparation for the National College Entrance Examinations (Lin and Chen, 1995) or over emphasize the depth and specifics of the subject content, but are lacking of consideration for promoting aesthetic sensibility, moral appreciation, deep intellectual development, and labor competency (Su and Su, 1994; Su and Su, 1995, Gao, 1998). The problems with textbooks and teaching materials, understandably, are mixed results of the country's history of science education, cultural tradition, political issues, and economic concerns. Nonetheless, since the current curriculum has begun a revision of philosophy and objectives towards achieving general science literacy that is in accord with that of GSL, renovations and/or innovations of teaching materials will also have to be carried out toward the GSL designs.

4.2.3. Instruction Methods. Current school science teaching is dominantly conducted in teacher-centered classrooms with lecture as the standard format. Demonstrations and student discussions during lecture are rare, while laboratory experiences and hands-on activities are too few. In addition, there is too much pressure of homework exercise, over-emphasis of textbook materials, and over-consideration of tests. All these result in passive student learning which lacks independent thinking, reasoning, questioning, and individuality. According to GSL, passive learning does not support its objectives for producing scientifically literate citizens. Thus, for teachers, while collective preparation for classes may be a good way to maintain the national curriculum standards and ensure the quality of classroom instruction, they need to develop more individualized teaching styles as well as approaches that actively engage students. For example, there is a need to develop real life based experiences and independent projects to encourage student initiatives and creativity, which enhance their critical thinking skills as well as their abilities in life applications and practical problem solving.

4.2.4. Teacher Resources and Quality. The lack of qualified science teachers has become a major hindrance for popularizing secondary school science learning as well as for elevating quality of the primary school teaching. This problem is even more challenging in rural areas, where 70 percent of the country's population resides but is unequally shared in the educational investments (Gu, 1999). While the solution of this problem depends largely on the national educational policies and budgets, the teacher

training programs at the normal schools and universities will have to be appropriately revised and improved toward the GSL objectives to ensure both teacher quality and innovations in classroom instruction).

4.2.5. Educational Funding and Quality. China's national science curriculum is intended to achieve equal standard and equal opportunity for all school children. However, the intense competition for resources and instructional quality has resulted in severe inequalities between "key" and "regular" schools in cities as well as between the urban and rural schools. In urban areas, the key schools are advantaged in receiving funding, obtaining qualified teachers or re-training them, using resources provision, etc. Their quality is better ensured and therefore, they attract more students than do regular schools. This causes even stronger competition for students to get in key schools and those who do get in noticeably receive better science instruction than those who do not. In addition, most senior secondary schools institute tracking programs of fast and slow classes within each academic track. Students who are on the fast track preparing for the National College Entrance Examinations usually receive preferential treatment in terms of teacher quality, classroom/lab facilities, and teaching materials. This inequality is further enlarged between schools in cities and rural areas for the same reasons; in some cases the lack of resources and qualified teachers becomes too severe in the countryside to even keep the curriculum going. This is against GSL. If not changed, China's science education will not succeed in reforming programs towards the GSL philosophy, less alone educating all children to become scientifically functional citizens.

4.3. Recommendation for Chinese Reform in Science Education According to GSL

Based on the above discussions on the Chinese social and economic demands for improving school science programs, their goals and objectives for reform in science education, and the GSL appraisal of the current school science curriculum and instruction, some recommendations can be drawn.

Firstly in course organization, the reform should implement the theme of holistic thought and systematic design in an overall curriculum plan by continuing the whole learning concept in the junior and senior secondary levels for the purpose of achieving popular science literacy. General science courses should be designed and organized systematically on concepts at the lower secondary level, rather than by disciplines. Similarly, courses unified with conceptual themes but not disciplines must be developed at the upper secondary level toward the GSL objectives and methodology for general science education purposes for non-college bound students.

Secondly in modes of instruction, the reform should encourage teachers to search and research for effective science teaching approaches that build individualized teaching styles and actively engage students in learning. While group preparation for classes can be continued on the grounds of ensuring the national standards and content coverage, each teacher's classroom conduct should be encouraged to work accordingly for establishing a student-centered climate of inquiry. Further, cooperative learning, extensive field observation and investigation around the local environments, internet search and interactive computer program use, and exploratory story telling should be

included in the curriculum to develop student real-life experience and the ability to conduct independent projects. Student initiatives and creativity must be promoted and encouraged by all available means. If lecture is used in classroom instruction, demonstrations, hands-on-activities, student discussions, and carefully designed lab experiments must be increased to help achieve student active learning.

Thirdly in textbooks and teaching materials, the reform must advocate the development of a broad collection of teaching materials that encourage diversity and creativity in content presentation, technology inclusion, cultural alternation and appreciation, and awareness in science and science professions. The materials must have an inherent theme toward the GSL philosophy and objectives, and hence support teachers in helping student acquiring scientific knowledge, systematic understanding, application and communication skills, critical thinking, and local and global awareness. Finally, when selecting and recommending textbooks and materials to all levels of schools, the national Education Committee must ensure conceptual continuity of knowledge and skills while minimize disconnection between science and other branches of study, such as history and social studies.

Fourthly in assessment of student learning, the reform must make a dramatic change from the current paper-pencil test only practice. Assessment methods always directly influence, in China it controls, the practice of teaching and learning. Testing in Chinese education today prioritizes the measurements of student factual recall of content knowledge while minimizes evaluations of other objectives required in the reform. Since science curriculum will be redesigned toward the GSL objectives, requiring teachers teach not only a strong foundation of knowledge but also ability and skills to apply it, the assessments must include the skills evaluation, such as the ability and creativity in using information technologies and solving real-life problems. The reform also calls for curriculum to help develop GSL based worldviews or philosophies of life with globally and scientifically established moral standards and ethical qualities. Thus, assessment tools must consist of measurements of understanding cultural and individual diversity as well as global, environmental, and systematical science understandings.

Lastly in preparation and professional development of science teachers, Mayer will discuss the challenges and difficulties for preparing teachers for GSL in Chapter 12 in this book. There are and will be many non-curriculum factors effect teacher preparation in China, but at least one thing is certain: Inquiry-based science courses must be developed at teacher preparation institutes, for which pre-service and in-service teachers are required to take. How teachers are taught will translate to how they teach. Thus, teacher preparation programs at normal colleges and universities must endorse the requirements of reform in school science curriculum and revise their programs accordingly.

5. CONCLUSION

China's contemporary pre-college science education faces great challenges in the country's rapid economic and social development. It is at the same time that school science programs are required to reform for the purpose of ensuring and invigorating

such developments by assisting in a cultural transformation towards democracy as well as supporting people's pursuit to global economy. A comparison of the objectives of reform in Chinese science education with that of GSL concludes that the GSL philosophy and objectives can be used to effectively directing and assisting the reform. A qualitative analysis of the current Chinese science curriculum at the primary and secondary levels according to GSL further indicates that while the primary curriculum is well designed using a systematic and conceptual approach, the secondary curriculum lacks integrity, continuity, and integration. In addition, the insights gained from other comparative educational studies as well as international education exchange programs in the past two decades also indicate that serious flaws exist in the current school system as well as in the curriculum design and instruction, which are called to improve toward the GSL design. It is therefore clear that the potential of GSL in directing such a reform is both promising and ensuring. Thus, substantial improvement is suggested based on the GSL objectives on the grounds of curriculum design, teacher preparation, classroom instruction, assessment, and materials development, which will help realize China's desired kind of reform.

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CHAPTER 9: NEEDS ASSESSMENT AND EDUCATIONAL CLIMATE FOR GLOBAL SCIENCE LITERACY: THE CASE OF CYPRUS

Rosanne W. Fortner, The Ohio State University, USA,
and C. P. Constantinou, University of Cyprus, CYPRUS

1.INTRODUCTION

Global Science Literacy has as its goals to stimulate an interest in science, represent modern technological goals of science, develop international understanding, relate science to social needs, and develop thinking and problem solving skills for the 21st Century. Such an approach is proposed as viable on an international basis for conceptual strength in integrated science courses. Assessment of GSL's potential in Cyprus serves as an example of preparations needed and concerns to be addressed if GSL is to become the basis of the science curriculum. Toward this end, a survey of teachers throughout Cyprus identified teachers' priorities for environmental issues and system science concepts their students should know, the teachers' knowledge of those concepts and issues, and their current levels of teaching them. This chapter will discuss the teachers' relative perceptions of local and global understandings, Earth systems science, and teacher education issues involved in fostering Global Science Literacy.

Education about the environment and about the Earth systems sciences could provide information to answer important questions about some of the most relevant and pressing science-based issues of the 21st Century. The late Isaac Asimov wrote, "Increasingly, our leaders must deal with dangers that threaten the entire world, where an understanding of those dangers and the possible solutions depends on a good grasp of science. The ozone layer, the greenhouse effect, acid rain, questions of diet and heredity — all require scientific literacy" (Augustine, 1998). In a world focused on the competitive testing that compares one country to another in science achievement, cooperation among countries to raise the science literacy of all requires a noncompetitive, interdisciplinary approach to the entire curriculum. Global Science Literacy begins with Earth systems education, since ESE applies all the sciences to understanding and dealing with the natural processes and human-generated hazards of modern living.

2. EMERGING CONCEPT OF EARTH SYSTEMS EDUCATION

A growing number of scientists and educators are forwarding the notion that the appropriate focus for all of science in the curriculum is Earth, with its interacting components of water, land, air and life, and with its instant relevance and interest for students (Fortner & Mayer, 1998; Barstow, Geary & Yazijian, 2002). Education about the Earth system emphasizes the interdisciplinary aspects not only within science but also of science with the other subjects of the curriculum as well.

System sciences in general have been characterized as operational in *levels* of organization of nature rather than in distinct categories or disciplines (Lazlow, 1972). The disciplines made great contributions over the centuries through their

reduction of big ideas into their components, but "in the twenty-first century, science will be in a position to begin putting the pieces together, in order to seek a synthetic or holistic understanding of Nature. The Earth sciences are inherently synthetic and are therefore uniquely placed to lead this development" (Alvarez, 1997). Mayer & Fortner (1995, 2002), Fortner & Mayer (1998) and colleagues at all levels of science education suggest that the concept of the Earth as a system could be central to science curricula worldwide, replacing the current disciplinary approach with an approach that recognizes the importance of concepts from all the sciences. In turn, Earth systems education can form the basis of global science literacy.

The key elements of Earth systems education are contained in a simple Framework of Understandings developed by scientists, science educators, and classroom teachers (See Appendix A). These elements are also the basis of what many feel is important in global science literacy as well as much of what is traditionally considered the realm of environmental education. The scientific thinking and decision-making aspects of Earth systems education are appropriate bases for approaching environmental issues rationally.

The urgency of information about environmental systems, which justifies the position of values and stewardship as the first two Understandings, was noted by Dr. Jane Lubchenco (1998) in her presidential address to the American Association for the Advancement of Science: "We can no longer afford to have the environment be accorded marginal status on our agendas. The environment is not a marginal issue, it is the issue of the future and the future is here now." Not only do studies of the environment offer rich experiences with real data, and the need to consult many disciplines in search of answers, but they also provide a reason for doing science and a means of introducing the value of good stewardship of resources.

3. NEEDS ASSESSMENT FOR ESE/GSL

Are educators in Mediterranean countries aware of the importance of Earth systems concepts and the value of environmental studies for the development of global science literacy? The TIMSS-III data show only one Mediterranean country (Italy) above the mean score for Grade 8 measures and six below the mean (Martin, et al, 1999). However the test bank includes an overwhelming proportion of items testing knowledge of concepts in single disciplines. Cyprus students did best on environmental topics and had lowest scores on Earth science topics within their own country's sample, but internationally the country scored below the mean in both areas. Traditional competitive test scores may not be a good indicator of the development of global science literacy, but at this point in science education development they are serving to alert countries of needs they might have.

An administratively simple teacher perception survey offers a look at how an educational system may come to realize its own needs and preparation for environmental and/or Earth systems education. The method has been used successfully in identifying needs for Great Lakes education in North America (Fortner & Corney, 2002), and to find discrepancies between teachers' knowledge and priorities for teaching (Fortner & Meyer, 2000). The technique now offers a first step in assessing a region's potential interest and preparation for global science literacy. First a number of topics are identified for their relevance to GSL goals.

These should include some global environmental issues and some local ones, as well as topics or concepts representing the seven Earth Systems Understandings. Three questions are asked about each selected topic:

- How important is it for students in your school to know about the topic?
- How much do you know about the topic?
- To what extent are you currently teaching about the topic?

After they rate each of the topic areas three ways, the responding teachers are invited to provide reasons for not teaching some of the topics, and to identify the topics about which they wish to know more. They suggest their preferred mode of acquiring new science information for teaching, and conclude by providing some demographic information about themselves and their teaching situation.

The nature of the three key questions allows education professionals to examine whether the goals of GSL would be acceptable in the classroom and how much teacher preparation would be needed to implement it. Responses from teachers at different grade levels can indicate where the key topics might fit best based on teacher preparation, and how the topics might be sequenced for building learning through successively more complex and global understandings.

4. THE CYPRUS EXAMPLE

In Cyprus there is little precedent for integrating the sciences, even though the gymnasium level (middle school) curriculum was initially organized to foster multidisciplinary science experiences each year (Ministry, 1996). An exception currently being pilot tested is the offering of Natural Science ("physiognostica") in selected lycaea (high schools). TIMSS performance by Cypriot students indicates a lack of preparation in the area of physical geography and on other items that are somewhat representative of Earth systems content (Martin, et al, 1999). The assumption is that implementation of GSL, as the science curriculum goal, with ESE as the mechanism and environmental issues as an integrative medium, would foster greater science knowledge because of the relevance of topics and interrelationships of information.

Objectives of the Cyprus study were to answer key questions:

1) What priority do teachers place on certain Earth systems and environmental topics for students in their schools to know?
2) How do teachers assess their own knowledge levels about these topics?
3) To what extent are teachers currently teaching the topics?
4) What differences exist between primary and secondary teachers with regard to their priorities for, knowledge and teaching of the topics?
5) In what forms do teachers prefer to receive information and curriculum materials?

4.1. Methods

A survey was developed listing 10 environmental issues identified by a focus group of Cyprus teachers, and a final two added by the authors based on observation of actual problems or potential issues faced by the island nation. The list of environmental issues salient for the focus group of teachers included the first ten

items below. Soil loss and imported species were added based on evidence of their existence in the country.

Ozone depletion	Global warming
Trash disposal	Tourism pressure
Air pollution	Acid rain
Extinctions of living things	Sea pollution
Oil spills	Access to fresh drinking water
Imported species	Loss of soils

Another ten topics were assembled based on the Framework of Understandings to represent Earth systems content that curricula might include. Understanding #2 was covered in the environmental issues section, and geography and ecology of Cyprus were included because ESE uses the local environment for developing relevance of more global themes. The topics thus included in the ESE section, and the Understandings from which they were inferred, consisted of

Arts in science teaching (ESU #1)	Uses of technology for science (#3)
Interactions of air, water, land, life (#4)	Processes of science (#3)
Change over periods of time (#5)	Energy flow in nature (#6)
Careers in science (#7)	Earth's place in space (#6)
Ecology of Cyprus (local relevance)	Geography of Cyprus (local relevance)

The survey was administered to two groups of teachers:

1) secondary science teachers at a required briefing held by the Ministry of Education and Culture. Respondents were science teachers of the Gymnasium level (grades 7-9) and the Lyceum level (grades 10-12), in the four regions of the Republic of Cyprus (Fortner & Constantinou, 2000).
2) primary teachers in schools from the four Cyprus districts. Seven teachers participating in an Environmental Education course in the University of Cyprus' new graduate program for Learning in Science each gave the survey to at least 10 other primary (grades K-6) teachers in their own or other schools.

4.2. Results

Usable surveys were received from 96 primary and 116 secondary teachers. Secondary teacher respondents included 53 males and 44 females, with an average of 18 years' teaching experience (range 3-30 years). They had bachelors degrees in science subjects or geography, and only 9 had masters degrees. All were teaching in public schools and 90% were from cities rather than villages of Cyprus. Among the primary teacher respondents were 19 males, 36 females and the rest not reporting gender. They had been teaching for an average of 11 years (range 1 – 33 years), and 6 had Master's degrees. Most taught in cities of Cyprus, but 26 listed villages instead. Given the nonrandom selection of the sample the ensuing analysis is not generalizable to other groups of teachers, but the sample size makes it a good representation of the perceptions of Cyprus teachers.

Since Understanding #2 relates to environmental topics, and the other six understandings in Earth systems education were also part of the survey, all 22 topics were analyzed as a single set. The authors acknowledge the weighting of

environment in the list, but maintain that the interdisciplinary methods of ESE and the relevance it seeks make environmental studies a possible mechanism for getting all of ESE into the curriculum. Putting the 12 environmental issues together with the ten ESE topics allows the results to show the relative use of environment compared with other more general topic areas.

4.3. Priority

The topics selected as highest priority by the primary teachers (most important for students in their school to know) included three environmental issues and three ESE topics, in the order shown in Table 1. The environmental issues represented one visible local issue (trash disposal, rated 3.7 out of 4), and two global issues with much local visibility (air and sea pollution, 3.7). High priority ESE topics (3.7) were Earth's place in space, a unit taught only in primary schools, and an item with obvious local relevance, ecology of Cyprus. Among secondary teachers the highest priorities were assigned to four environmental issues (ozone hole and air pollution, both 3.9, acid rain and sea pollution, 3.7) and one ESE topic (ecology of Cyprus, 3.7). Both primary and secondary teachers named introduced species among the lowest priorities, with primary also adding careers in science, soil loss, and interactions of water, land, air and life. Secondary teachers also placed low priority on change over time and the arts in science teaching.

Table 1. Priority for Cyprus students to learn about selected issues and topics for Global Science Literacy.

	Primary Teachers		**Secondary Teachers**	
	Topic	Priority	Topic	Priority
Highest	Trash disposal	All 3.7	Ozone hole	3.9
	Air pollution		Air pollution	3.9
	Sea pollution		Sea pollution	3.7
	Ecology of Cyprus		Ecology of Cyprus Acid	3.7
	Earth's place in space		rain	3.7
Lowest	Careers in science	2.3	Introduced species	2.7
	Interaction of systems	2.5	Arts in science tchg	2.8
	Introduced species	2.8	Change over time	2.9
	Soil loss	2.9		
Average rating	All 22 topics	3.27	All 22 topics	3.44

4.4. Knowledge and teaching level

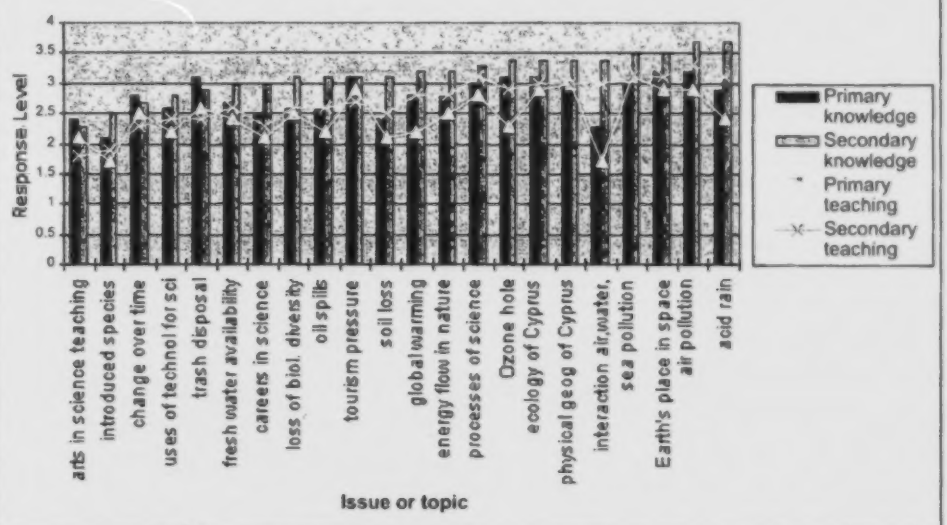
Teachers' self-reported knowledge of the 22 topics showed additional differences by teaching level (Figure 1). Primary teachers reported knowing most about air pollution and Earth's place in space (3.2 out of 4), while secondary teachers claimed acid rain and air pollution (3.7), sea pollution and Earth's place in space (3.5) as their most knowledgeable areas. The secondary teachers report teaching most about air pollution and the primary teachers sea pollution and physical geography (3.1 and 3, moderate teaching). Level of teaching of the topics was strongly correlated to

teacher knowledge (primary r = 0.87; secondary r = 0.97) as shown by the lines in Figure 1.

The relationships of topic priority to teachers' knowledge and teaching level were assessed for each teacher group as well. Again relationships were strong for both groups of teachers on both measures. Priority was strongly and positively related to knowledge (r = 0.76 for primary teachers and .83 for secondary) as well as to amount of teaching (r = 0.73 and 0.84, respectively). Differences between primary and secondary teachers on overall measures of topic priority, knowledge and teaching were all significant (for priority, $p < .05$; for knowledge and teaching, $p < .001$).

When asked why certain topics are not being taught, teachers responded most often that the topics were part of the responsibility of another subject area or another grade level, or more generally they were "not part of the curriculum." "It's not my job" is a legitimate reason for not doing a particular task. If it is important,

Figure 1. Self-reported knowledge and level of teaching of issues and topics



however, that primary students be introduced to science careers, or that aesthetics become a way to meet certain learning styles in secondary schools, teachers are not responding to that information. "There is not enough time" was another common reason for not including topics. Perhaps the length of the school day or contractual constraints of a strong teachers' union do not allow for additions to the curriculum that would enhance global science literacy to the extent that some of these topics are expected to do.

Where do teachers get their environmental information, and in what form would new instructional materials best be received? Primary teachers in 2002 reported getting most of their information for teaching about the environment from television, with secondary sources of workshops/classes and organizations (Figure 2). Secondary teachers in 1999 reported their information sources as specialty

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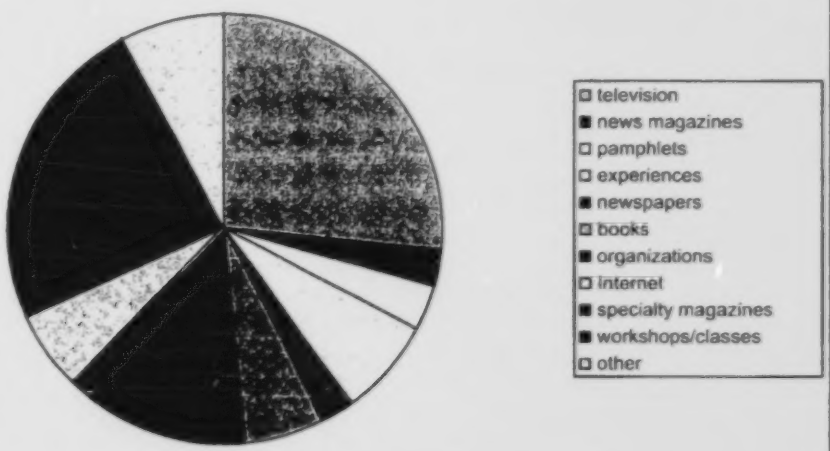
magazines and books, with television a third choice and workshops and class a distant fifth.

The form of teacher education preferred by Cyprus primary teachers is a weekend workshop (30%) followed by one-day or credit workshops (16% each). Secondary teachers overwhelmingly preferred experiences bearing university credit (55%) with one-day workshops also acceptable (18%). If environmental education materials are to be useful to them, the form for primary teachers should be lesson plans, followed by audiovisual materials and then reference materials of various kinds. Secondary teachers want audiovisual aids and textbooks or reference materials.

Figure 2. Primary teachers' sources of environmental information



5. DISCUSSION

It is clear that Cyprus teachers at all K-12 levels see the set of selected topics as important for their students to learn (20 of 22 topics rated 2.7 or higher out of 4), and this alone might be used as justification for new efforts at implementation of steps toward global science literacy as exemplified by Earth systems education. Of the five topics rated most important at both levels, 3-4 were environmental issues and the remaining were the local-to-global combination of ecology of Cyprus and Earth's place in space. To continue schooling children without environmental studies is not educating them for informed global citizenship, and perhaps the teachers' ratings of issue importance are a signal that a curriculum to include the local and global environment would be accepted.

Local citizenship has an important environmental component too, but with the exception of trash disposal the local issues were rated as less important than the global ones. This result should raise some concern. While issues such as the ozone hole, air pollution, acid rain and sea pollution are all very important; they are not the kinds of issues that people see as requiring their personal commitment to the environment. It is easy to espouse learning about these issues, learning to shake our heads solemnly when confronting their global severity but continuing with the local lifestyles that contribute to them. The mass media and school textbooks with global viewpoints are probably responsible for the salience of global issues in teachers' thinking. At the same time, issues like soil loss (2.9 and 3.2 for primary and secondary, respectively) and introduced species (2.8 and 2.7), both obvious to a newcomer as issues that should be of local concern, are rated the lowest importance of the issues. Perhaps these are not seen by teachers as something that children can address personally, but they are certainly issues that have local relevance and can be seen in many examples, compared to the ozone hole and acid rain which are much more abstract and distant issues. As for the issue of trash disposal, the primary teachers found it very important but secondary teachers did not. Any early training in recycling and rubbish control is likely to go without reinforcement in later grades.

"Arts in science teaching" was a topic rated by secondary teachers as having low priority. Global education requires an holistic view, and countries such as Spain are trying to develop methods for addressing such a view through an interdisciplinary curriculum. Lillo and Lillo (2002) describe a cross-curricular approach for high school and first year university students that follows the ways ancient Greeks and Romans understood nature. According to the authors, "The objectives for these activities are to develop positive ethical and aesthetic attitudes about the role of human beings in nature" (p. 137). Adaptation of this approach and materials could assist in meeting the Framework Understandings #1 and 2.

Two issues rated low in priority, system interaction in primary years and change over time at the secondary level, are key to Earth systems education. If students are not taught at an early age that "everything is connected to everything else" (Commoner, 1969), it will be difficult for them to integrate science topics to answer important questions. Understanding the ecology of Cyprus, for example, one of the priority topics, requires awareness of the relationship of the hydrologic cycle and soil characteristics to the vegetation types supported at different island sites. Planting a tree for nature study will not succeed without attention to the water and soil conditions required by the selected tree species. As for change over time, a low priority for secondary, the teaching of organic evolution is key to modern biological principles, and the range of system changes becoming apparent in global climate change stands to alter not only ecology but human endeavors for the future. Adding ESE to the curriculum would assist with preparation of students for 21st Century needs and demands for decision making.

Finally the issue of introduced species, low priority for all Cyprus respondents, is a major factor in ecological change worldwide. The Great Lakes region of North America sees the introduction of several new species each year, and San Francisco Bay has over 250 exotic species now impacting its ecosystem. Nature in its normal state is in dynamic balance, and new species introductions disrupt that balance, nearly always in negative ways. Cyprus has no agricultural inspection at

Customs, and people casually bring in attractive or culturally important plants from other parts of the world to decorate their island homes and gardens. One has only to look at the impact of the eucalyptus trees, brought in to dry up wetland areas, to see how successful imports can be. Even in the sea, invaders such as *Caulerpa taxifolia*, an aquarium plant apparently discarded in the western Mediterranean, are threatening the naturally diverse assemblage of sea organisms. Nowhere in the media or textbooks are such issues addressed; yet they have the potential to shape life in the Mediterranean region for centuries to come.

6. CONCLUSION

Global science literacy is a requirement for sustainable lifestyles in the 21st Century. A combination of knowledge, awareness, and life skills in dealing with the environment and the interacting forces of Earth is needed by all inhabitants of the planet. If school is to be part of that preparation for survival, the science curriculum is key.

Like other Mediterranean nations, Cyprus has room to build a stronger science curriculum. With this research we have identified a list of priority areas that would be acceptable in that curriculum, and the ways that teachers learn about the topics. Combinations of public mass media and targeted publications can strengthen the science knowledge of the teaching population, and the teachers clearly indicate that topics are used in the classroom in proportion to how much the teachers know.

If the providers of science teacher education and curriculum materials wish to further increase the possibilities of teachers using Earth systems topics, the research has identified modes of inservice education and instructional resources that are most desired at the primary and secondary level. Developing courses for credit, with audiovisual and reference materials for secondary teachers would best serve that group in implementing new topics in teaching. For primary teachers the new topics are best introduced through classroom activities and lesson plans available through weekend workshops.

Using this simple survey format thus provides a concise but powerful needs assessment tool and helps identify the potential for success in curriculum innovation. The importance of global science literacy warrants attention of all Mediterranean countries to whether their schools' potential for contributing to such literacy is being met. Resources exist throughout the region for addressing these needs; what crisis of environment will convince educators that the time for fostering global science literacy is now?

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CHAPTER 10: SPANISH CURRICULA AND GLOBAL SCIENCE LITERACY

José Lillo, University of Vigo, SPAIN

1. INTRODUCTION

In this chapter I analyze the science curriculum proposed by the Spanish Ministry of Education and how it is applied in the different Spanish regions with their own educational authority. The curriculum is compared with the Global Science Literacy philosophy suggested by Mayer & Kumano (1999), in order to develop an approach to international science literacy based on the conceptual outline "Earth as a System".

Globality, integration, the need of incorporating notions of History and Philosophy of Science and teaching them constructively, as suggested by Science-Technology-Society (STS) proponents and proposed also by those introducing Global Science Literacy (GSL) as a curriculum plan for the future, are common considerations among the general objectives of the Spanish curricular plans. This notwithstanding, the main difficulty lies in overcoming the long-existing disciplinary approach prevailing both in the curricula of the different Spanish regions and in Pre-service and In-service Teacher Training Programs, which tend to differ from the aforementioned considerations.

2. CURRENT TENDENCIES IN SCIENCE TEACHING

In spite of distances and different teaching contexts, the papers of the recent Conferences on Geoscience and Science Teaching (Southampton, 1993; Hawaii, 1997), as well as the works by authors of different nationalities (in English, Spanish or French speaking areas) show common ideas and concerns on the following facts:

> Socializing education in terms of expanding the compulsory period of school attendance invalidates Science teaching programs exclusively based on inductive approaches.

Scientific Literacy for all citizens, as proposed in Project 2061 (AAAS, 1989, 1993), and Science Teaching and Society proposals, are common in the recent Spanish curricular designs (Aguilar, 1999), and they are in mind of many Science Education Research Groups in America, Europe and other countries (vide Behrendt et al., 2001).

> Considering the ecologic paradigm present in the daily life of all citizens implies the need to find a basis for curricula in the students' contexts and their real problems, interests and actual or possible concerns. This leads to assume contexts and globality as curricular sources.

The general acceptance of this paradigm in Spain has become evident starting from the last publications on Science Research Education and especially in the recent VI International Congress (Barcelona, 2001). In this Congress, communications and simultaneous symposia relative to the implications STS (Science-Technology-Society), Scientific Literacy and to the consideration of Global Problems were

dominant. See, among others, the references of Lillo (2001), Edwards and al. (2001), González and al. (2001) or Marco (2001).

New ways of understanding and teaching Science within an interdisciplinary structure of knowledge are also supported by the reconsideration of the roles of History and Philosophy of Science in the new global perspective (vide Serres, 1991; Fourez, 1994; Mayer & Kumano, 1999).

The holistic view for actual global problems and their solutions requires a combination of disciplines. Some researchers (as Mayer, 1995, and Lillo, 1999a) use integration as a basic concept. Others (Fourez, 1994,1997; Rumelhard, 1998) adopt interdisciplinary positions.

Fourez (1994, 1997) thinks that global problems can be considered as projects to deal with and therefore be solved with a methodology of construction of "islands of rationality". The notion of "island of rationality" (Fourez, 1994) is linked to the concept of interdisciplinarity around a project, using the pattern of the projects common in diverse scientific and technological fields. Around a project a provisional theoretical model is made, in order to discuss and to act in the development of the project solutions. It uses the metaphor of the island emerging from the ocean of ignorance. To discuss and to act in a given situation, it's necessary to build an "island" of appropriate rationality. Therefore it's a theoretical construction that allows us to specify the situation in order to have a rational discussion to follow a certain procedure in the solution of problems that the project outlines and to reach an agreement on action and of the theoretical construction.

Normally to advance in the theoretical pattern we need to open "black boxes", which need precise theoretical constructions of a certain science. This methodology is used too by some European researchers adopting Science Literacy perspectives and may be a useful class strategy in a Global Science Literacy context.

The problems found when trying to analyze the origin and application of scientific knowledge in the globalization process have favored STS-based methods for Science teaching and Scientific and/or Technological Literacy plans. Such plans and methods have progressively incorporated ethical and aesthetic aspects, and different viewpoints in which Science is understood in various cultures.

When the plan for Science teaching learning is put into practice, a social constructivism is approached, rather than a child-based one as in the so-called "Piagetian constructivism" (Marin and others, 1999, p. 481).

These facts have also influenced the curricular developments of different countries where a preference for some of the tendencies has been shown (as it most often happens), or where most of the tendencies have been attempted.

GSL philosophy tries to develop international science literacy, and the main features are the following:

Promoting a review of the role of History and Philosophy of Science, from the present standpoint under which Science is considered to be a constant construction process, and socially determined.

Adopting a conceptual rather than disciplinary organization of the curriculum, bearing in mind "Earth as a System, with Related Systems" as an all-inclusive element. The Earth Systems Science outline is then applied, therefore following the recommendations suggested by the Earth Science Committee (1988).

Offering a socially constructive proposal and considering that Science develops its own procedures and expressions, useful and necessary in order to reach the intended Global Education.

Believing that men and women are a part of the Nature they interact with, not only users and beneficiaries. Their actions may result in important alterations of other subsystems.

Conceiving the use and development of technologies as a way of obtaining a better knowledge of the Earth and preserving its resources, not as a cultural and social economic competition.

Proposing models for Teacher Training in Global Science (Mayer, 1992, p.70), in order to jointly study and develop teaching units from the GSL perspective.

In my opinion, GSL and other similar proposals face the following essential problems: (1) How can scientific knowledge be built on the basis of the global problems studied in GSL (Lillo, 2001)? (2) How can pre-service and in-service Teacher Training be approached in different countries so that it can influence the learning-teaching experience as outlined in Global Science Literacy?

In order to modestly contribute to achieving an international science literacy approach, I hereinafter analyze Spanish curricula commenting on similarities and differences with the GSL philosophy, and bringing out the main disagreements and problems to be solved.

3. COMPARING SPANISH SCIENCE CURRICULUM WITH GSL

The current Spanish Educational System is a result of the 1990 General Planning of the Educational System Law (LOGSE, according to the Spanish acronym). The Spanish Ministry of Education issues royal decrees regulating the development of the 1990 law, taking into account the different Spanish regions (the so-called Autonomous Communities). Each region adapts such regulations with regard to its peculiarities, always under a general framework of minimum requirements, out of which the curricular proposal is open and flexible. With the Central Government's minimum requirements as a starting point, Curricular Developments are carried out in each region, as a basis for the different educational institutions. Here, curricula are finally defined.

In spite of the diversity that might appear from such flexible and open rules, the Science curricula are not very different among the Spanish regions, except for some unimportant variations in focus or regarding the language, culture or natural peculiarities in each area. The general plan followed by all the regions when the educational levels are being structured is as follows:

Early Childhood Education, with two phases: 0 to 3 and 3 to 6 years of age. Only the second phase is compulsory and approached from a globalizing perspective, as outlined in Global Education. Science is included in Physical and Social Environment Studies.

Primary Education, with three phases: First Phase (6 to 8 years of age), Second Phase (8 to 10 years of age) and Third Phase (10 to 12 years of age). There are seven Areas of Study, one of which (Knowledge of the Natural Social-Cultural Environment) is devoted to studying Science from a globalizing and integrated perspective.

Compulsory Secondary Education (ESO in Spanish), with two phases: First Phase (12 to 14 years of age) and Second Phase (12 to 14 years of age). The studies are to be developed with an integrated focus. Natural Sciences are studied in the First Phase as an integration of all Sciences, and Biology-Geology and Physics-Chemistry in the Second Phase, all of these within an Area of Study called Science and Technology.

Post-compulsory Secondary Education (ESPO in Spanish), from 16 to 18 years of age. Four different modalities allow structuring the Spanish high school choosing from different options, which will determine individual access to University studies. Such modalities are: Technology, Human and Social Sciences, Arts, and Health and Natural Sciences. Table 1 summarizes the Science Modules existing in each modality, and Optional Modules.

Table 1. Science modules

YEAR	TYPE OF MODULES	MODALITY OF POST-COMPULSORY STUDIES			
		Health and Natural Sciences		Technology	
Year 1	Science Modules	• Physics-Chemistry • Biology-Geology		• Physics-Chemistry	
Year 2	Science Modules	OPTION A	OPTION B	OPTION A	OPTION B
		• Physics • Biology	• Chemistry • Biology • Earth and Environmental Science	• Physics	(None)
	Optional Modules	Geology	Geology	Geology	Geology

In the exams previous to admission to the University, only the compulsory modules are under assessment, such as the optional module called Earth and Environmental Sciences, but not Geology. As a consequence, students devote less time, effort and interest to this subject, since they only feel the pressure of the modules that will allow them to enter University.

All the educational stages follow curricula conceptually organized around three types of contents: conceptual (related to facts, concepts and principles); procedural (related to procedures and skills); and attitudinal (related to attitudes, values and norms). Mathematics is considered as an Area of Study different from Science, and therefore separately studied. Once a general outline has been drawn, we will now consider the curricular features of each stage in detail, and how GSL can be applied.

3.1. Similarities and differences between the Infantile Education Stage and GSL

The curriculum is developed in three Areas of Study, including the Physical and Social Environment. The conceptual contents proposed for the Natural Physical Environment refer to elements and forces of Nature, specifically to the Sun, light, water, air, Earth, minerals and living beings in the soil, changes in the climate and its consequences, living beings (animals and plants) in the child's environment and other living beings. Among the procedural contents, most attention is paid to

observing, perceiving, distinguishing and identifying skills, among others. Enjoying the pleasure provided by natural items themselves or when they are artistically reproduced is the main aim among attitudes, values and norms.

These objectives are clearly identified with GSL for these ages, including the development of aesthetic attitudes (vide Mayer, 1992, p. 69; 1995; 1999). Moreover, globality is understood as directed towards the development of an integrated language where not only knowledge, but also musical expression and body and mathematics languages participate. This stage needs to be changed very slightly only in order to be adapted to an international curriculum based on GSL. On the contrary, however, Pre-Service and In-Service Teacher Training curricula do need to be transformed.

3.2. Similarities and differences between the Primary Education Stage and GSL

Extracting the ideas that are common to the proposals of the different regions of Spain in relation to the Central Government's proposal, I observe that the basic purpose of this stage is to allow students to integrate themselves in society in a critical and creative way, having acquired basic knowledge. Also, the personal independence that started in the previous stage is reinforced. Among the objectives proposed in order to reach the aforementioned aims, the following are in accordance with GSL:

Aspects for developing aesthetic sensitivity and enjoying works of art, even if the perception of beauty in Nature is assumed and therefore not mentioned.
Developing simple procedures in order to obtain information in problem-solving situations.
Identifying and producing questions and problems arising in daily life.
Planning and carrying out group activities, under democratically agreed-upon rules.
Appreciating basic values in social and political life and fellowship, and morals too.
Understanding how natural and social happenings and phenomena in the environment are related, and actively contributing to defend, preserve and improve them.

From all the groups of contents proposed for the curriculum, those related to Science are mentioned hereafter. Due to the nature of the focus, where topics belonging to scientific disciplines and social sciences are jointly considered, they are to be tackled in a global and integrated rather than in a disciplinary way. The main scientific groups of contents are the following:

The human being and health.
The physical environment and the living beings.
Materials and their properties.
Landscapes of the world (landscapes of each Spanish region).
Machines and equipment.
Mankind and energy.

The group of contents most specifically related to Geoscience is that of the physical environment and the living beings, where the following concepts are developed:

Geologic materials in the region (rocks and minerals).
Air and water.
The Universe.
Basic features of the living beings (animals and plants) in the environment.
Living beings' interactions.
Human impact on the environment.

An approach to Science in terms of simple observation, gathering and classification of data, systematic observation of animal changes and features, and debates on different problems (energy, human impact on the environment, human responsibility over the environment) are common among the proposed procedures.

Among the attitudes, the following are dominant: sensitization toward precision and rigor in the observations and measures, sensitization toward the problem of rational use of water (it is a problematic resource in central and middle Spanish regions) and intelligent use of energy. Some of the aspects brought out coincide with some of the principles in the GSL approaching, above all with regard to some of the topics dealt with, development of aesthetic attitudes and initiation to democratic behaviors among others. Although focusing in proposals closer to that of the GSL would not be a problem, most teachers have refused to accept the flexibility and freedom offered by the Curricular Project, often demanded as a routine. These teachers follow the proposals in their textbooks, adapting their teaching to the curricular development planned by a certain publisher. Moreover, textbooks for Primary Science Education are written frequently by Secondary Teachers with a disciplinary training and their point of view dominates over globalization or integration schemes.

3.3. Similarities and differences between the Secondary Education Stage and GSL

The flexibility of the curriculum is especially stressed during this stage. Similarly, teachers pay particular attention to developing the curricula in their regions according to their peculiar features. A team from each educational institution designs a Curricular Project, and Science teachers jointly plan the curriculum for their modules. The Secondary Education curriculum comprises nine or ten modules, depending on whether the given region has a language other than Spanish. The module devoted to studying Science is called "Natural Sciences".

The general aims of this stage are formulated in perfect accordance with the GSL philosophy, as can be seen in the following propositions, common to all the Spanish regions:

Understanding and expressing scientific language, both written and spoken.
Managing basic concepts in Science of Nature in order to scientifically interpret natural phenomena.
Applying individual strategies, consistent with Scientific procedures, in problem-solving situations.
Planning and executing tasks in teams.
Applying knowledge about natural elements and living beings in order to enjoy the environment.
Identify and assess how Science improves human living standards, and also the negative consequences of Science and Technology.
Developing a critical and well-founded attitude towards the main present problems derived from Science and Technology.

Appreciating scientific knowledge as a constant construction process, always evolving and under review, and depending on the given features and necessities in society.

Table 2. Topics studied in the Science Modules

- The Universe.
- Planet Earth: Materials and Dynamics.
- Living Beings.
- The Human Being.
- Features and Interactions Among Natural Elements.
- Universality in the Composition of Materials. Structures.
- Classifying Materials. Diversity.
- Chemical Reactions.
- Movements and Forces.
- Electricity and Magnetism.
- Radiation.

The main topics proposed for this stage are those stated in Table 2. In the first phase, the curriculum of the module "Natural Sciences" presents topics from the four fundamental branches of Science (Physics, Chemistry, Biology and Geology). In the second phase, a division may be drawn between two groups of topics, taught by different specialist teachers: Physics-Chemistry and Biology-Geology. A further possibility for this stage is to offer a higher number of optional modules, for the students to start shaping their choice in the next stage (16 to 18 years of age).

The Biology part of the Biology-Geology module in the last year should focus on considering living beings as systems of cells, organisms and ecosystems, with a special emphasis on nutritional interaction and energy flow. Similarly, the Geology part is proposed to focus on long-term changes, especially the "deep time" mentioned in the GSL guidelines at Chapter One.

The laws organizing curricula recommend disciplinary integration and inclusion of relevant current topics, such as environmental issues, health, peace education, etc., consistent with a Global Education and specifically considered to promote Global Science Literacy. Nonetheless, the specific university training received by the teachers of this stage is one of the main difficulties in bringing the curricula closer to the GSL model. The textbook line, already commented in 2., only worsens the situation. The teacher's books contain complete plans, activities and how to develop them, restraining any possible stimulating investigations within an updated curriculum.

3.4. Similarities and differences between the Post-Compulsory Secondary Education Stage and the GSL philosophy

The contents of the Physics and Biology modules studied in the second year of this stage are more specific and specialized than Physics-Chemistry and Biology-Geology in the first year. This can be observed in Table 3 and Table 4 (the contents

included are those common to the different Spanish regions).

Table 3. Physics-Chemistry topics.

PHYSICS CURRICULUM (YEAR 2)	PHYSICS-CHEMISTRY CURRICULUM (YEAR 1)
1. Physics Constructs.	1. Approximation to Science Constructs.
2. Universal Gravitation.	2. Mechanics.
3. Dynamics of Rotation.	3. Energy.
4. Fluids.	4. Materials and Transformations
5. Vibration and Waves.	5. Electricity.
6. Electromagnetism.	6. Electric Nature of Materials.
7. Light.	7. Organic Chemistry.
8. Modern Physics.	

Table 4.Biology-Geology topics.

BIOLOGY CURRICULUM (YEAR 2)	BIOLOGY-GEOLOGY CURRICULUM (YEAR 1)
1. Approximation to Biology Constructs.	1. Approximation to Science Constructs.
2. Cells and the Physical-Chemical Basis of Life.	2. Structure and Evolution of the Planet Earth.
3. Cell Physiology.	3. Dynamics of the Planet.
4. Chemical Basis of Heredity. Molecular Genetics.	4. Origin and Evolution of Living Beings.
5. Microbiology and Biotechnology.	5. Staying Alive. Nutrition and relations.
6. Immunology.	6. Life Perpetuation.
	7. Heredity: a Mendelian Approach.

Comparing the general aims and the development of conceptual, procedural and attitudinal contents in the different Science Modules, the following ideas appear:

Studying the disciplinary contents of each Science in depth, as a preparation to University studies.
Approaching Science at historic and social levels, and the fact that the validity of scientific knowledge is only temporary.
Developing scientific methodologies and investigator's skills applicable to problems in daily life
Developing scientist's attitudes such as curiosity, ability to criticize, etc.

The module of this stage that is closest to the GSL guidelines is the one called Earth and Environmental Sciences. There is a remarkable unity in the contents of this module among the different Spanish regions and a systemic approach is dominant in all of them, allowing up to 50% of the course to "The Earth Systems" contents. The topics proposed are :

1. Approximation to scientific works.
2. Mankind and the Environment.
3. Earth Systems.
4. Human Relations and Sustainable Development.

Almost all the regions tend to include relations between living beings and inert elements (as in Fortner, 1992), by considering bio-geo-chemical cycles and two time scales with different lengths: a close-historical scale and a geological-planetary scale (Espinet, 1998; Valdivia, 1998). There is a special development proposed for the northern region of Galicia (Lillo & Lucas, 1996, 1998, 1999), which offers a curricular development around the topic "The Earth, a Living Planet". The main idea tackled is jointly studying biologic and geologic issues through the bio-geo-chemical cycles and the two aforementioned time scales. The region of Madrid was the first to develop a plan for this module. After a 5-year experience, Nieda and Rebollo(1998), who had designed the first orientating items for the curriculum, confirmed its scientific adequacy to the ecological paradigm. Similarly, at cognitive and educational levels, it is consistent with the social constructivist model. Such model considers the students' knowledge as the starting point, in order to enlarge and re-organize conceptual, procedural and attitudinal frameworks. A way to organize the teaching-learning process by proposing real problems that arise in the students' proximity is also suggested. Finally, a consistent assessment is proposed, following these principles (Coll & Martin, 1993):

> Knowledge is acquired in different degrees of importance.
> The more extensive and complex the relations established are, the better the explanation will be understood.
> Learning always takes place in connection to contexts.
> Learning is most accurate when it can be applied to daily situations and generates further learning.
> Learning comprises knowledge, procedures, attitudes, values and norms.

The flexibility that was initially reached and the participation of teachers in the development of a curriculum adapted to their specific contexts were very positive, but "what really altered the process was the first module textbook in 1996" (Nieda & Rebollo, 1998). Once again, we can observe how the flexibility that was originally designed in the Educational Law became a uniformity through the textbooks issued by different publishers.

This optional subject is probably the most consistent one regarding the GSL philosophy, although it has been noted that Science teachers find great difficulty in teaching it, due to their disciplinary university training. The fact that the curriculum implies several branches of Science (Biology, Geology, Social Science and Environmental Education among others) also constitutes a major handicap, in spite of the recent great effort that Research Groups are carrying out in the Science Teachers Education in order to incorporate an interdisciplinary curriculum taking in mind Scientific Literacy, Global Problems and STS implications. (See among other, the ESERA Congress from Roma, 1997, Kiel, 1999 and Thesaloniki, 2001, or the VIth International Congress of Science Education, Barcelona, 2001).

3.5. Current topics studied on a cross-issue basis

Environmental and other issues should be dealt with in the Science curriculum of the Primary and Secondary Education stages. Furthermore, important current issues

such as Environmental Education, Consumer Education, Health Education, Peace Education or Ethics and Civics should be tackled from a cross-discipline perspective, so that they are studied from diverse viewpoints related to different areas of knowledge. These topics are fundamental in GSL, although they are not compulsorily stated in any curriculum. The Ministry of Education and institutions from different regions have issued several monographs in order to contribute to the teaching. Some of these topics are offered as optional modules in the Secondary Education stage of some regions, but there are noticeable divergences in the names. Some of these modules are "Environmental and Health Sciences", "History of Science", "Computer Science", related to premises from the GSL approach.

Obviously, approaching the GSL philosophy through cross-issues is difficult and problematic due to the fact that it is not compulsorily stated in curricula. Nonetheless, important activities have been carried out by teachers towards these modules and their development in the different Spanish regions, as an approach to a global education. (Yus, 1996, 1997).

4. OTHER PROBLEMS THAT MUST BE OVERCOME

The Spanish Educational Law clearly expresses an intention to impose a constructivist methodology. This fact gave place to great efforts in promoting such method in the different regions through Teacher Training Plans in the Teacher Training Nets existing in each region. The main features of this promotion were:

Research papers were abundantly produced and presented in Conferences on Science Teaching. The main national reviews on Science Teaching (*Enseñanza de las Ciencias, Investigación en la Escuela*) published various theses on this topic. Nevertheless, the theoretical explanations of constructivist practice are ill founded, and the type of constructivism adopted is undefined (Marin et al., 1999).

Research on Mathematics and Physics has been thoroughly developed, to a much higher extent than on Biology and Geology. Besides, the latter have been studied from the perspective of teaching, rather than from the integrating view outlined by the GSL approach.

A remarkable variety of research groups on constructivist Science teaching can also be appreciated in all of Europe (see papers from the conferences by ESERA -European Science Education Research Association- and how different European universities jointly direct doctoral dissertations: the Swiss School with Giordan and others, jointly with some French universities, Viennot, Martinand, etc.). Similarly, curricula that are closer to the concepts of Scientific or Technical Literacy, or Scientific and Technical Literacy, have been adopted (Fourez et al., 1994, 1997). Therefore, in Spain and in Europe, this is a period of research for new ways of teaching Science, although both training plans and research projects have offered few practical applications. The practical applications that have actually been found have not been widely accepted by teachers, who feel unsafe before new methodologies. Their disciplinary university training has forced them to maintain their tradition of applying disciplinary teaching methods.

The fact that teachers reject new tendencies is aggravated by how Teaching Research magazines tend to search for theoretical bases, whereas, paradoxically, teachers want to find new "recipes" for direct practical application. And what is even worse, the research works published in such scientific magazines are not even read.

In his analysis of Scientific and Technologic Literacy, Fourez (1994) suggests that within their training courses, teachers should work in groups and put into practice some interdisciplinary projects in order to build what he calls "islands of rationality", and complement such projects with some punctual disciplinary aspects (opening the so-called

"black boxes"). This would be a way for teachers to be confident with the new curricular perspectives and methodologies, and become researcher-teachers. Nevertheless, it is not clear yet whether the interdisciplinary view proposed by some European Scientific Literacy tendencies adopted by the GSL scheme will be useful to train new researcher-teachers.

The main problem is still how to build knowledge from globality. The GSL approach tries to solve it by using integrating concepts, whereas in Europe various concepts are being dealt with in a different way: "scientific obstacle", "building islands of rationality". They are based on interdisciplinary Science schemes, and research groups in Spain are starting to be influenced by them.

5. POSSIBILITIES FOR PRE-SERVICE AND IN-SERVICE TRAINING

According to what has been said heretofore, bringing the Spanish curricular design closer to an international scheme connected with the GSL perspective is a matter of reforming pre-service and in-service teacher training curricula in terms of Global Science. The exclusive application of disciplinary bases must be overcome, and institutions have to produce a large amount of teaching materials for their distribution among teachers and their professional and scientific associations. Such a task is not easy to tackle, due to the educational authority of each Spanish region, and to the importance given to "hard Science" at the expense of "soft Science".

The question is whether this objective could be met by spreading a Global Science Training Plan for Science teachers, who would take part in a research perspective for producing educational materials. And then, how could this policy be applied, given the textbook-producing policy maintained by publishing houses?

6. CONCLUSIONS

1. The existing pre-university curricula in Spain contain some of the elements supported by the GSL outline, but they are not gathered around the concept "Earth Systems". Only in high school there is a module called "Earth and Environmental Science", with a truly systemic integrating perspective where around 50% of the contents are based on "Earth as a System".

2. Early Childhood and Primary Education are the stages offering the most possibilities for approaching an international science curriculum, due to their globalizing and integrating focus. Such an approach is less easily implemented in secondary education and high school, where the practical focus is predominantly disciplinary.

3. There is a growing sensitivity towards environmentalism and social constructivism; nonetheless, institutional action should be directed towards modifying pre-service and in-service teacher training plans in order to overcome an exclusively disciplinary approach to science teaching.

4. More and more teachers are attracted to the interdisciplinary view given by the cross-issue perspective applied when dealing with current issues; it would be

positive to include such perspective in a consistent compulsory curriculum.

5. The fundamental obstacle is how to co-ordinate educational research in order to build knowledge holistically from a global and integrated position. A further related matter is the positive or negative role of publishers towards a new international curriculum.

6. Developing teacher training courses on Global Science, following the model of PLESE (courses promoted by the Ohio University), would also imply connections and agreements among universities, and a further training for those conveying the information through the European framework.

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CHAPTER 11: EARTH SYSTEMS EDUCATION IN GERMANY

S. Hlawatsch, H. Bayrhuber, M. Euler, K.-H. Hansen, K. Hildebrandt, L. Hoffmann, E.R. Lucius, F. Siemer, Leibniz Institute for Science Education, GERMANY and W. Hassenpflug, University of Kiel, GERMANY

1. INTRODUCTION

In the past decades research in earth sciences has undergone a significant shift towards questions of global change. They contributed significantly to the understanding of planet earth as a dynamic system, which changes over billions of years. Furthermore it has been realized that humans as part of this system have an influence on the system earth. This resulted in an awareness, that the terms and circumstances of human existence on planet earth have changed radically since the beginning of the last century and will continue to do so during the next human life span. The international community has now recognized aspects of "global change" like climate change, sea level rise, floods, hazards and lack of resources as well as the quality of life as important issues for national and international action (see "Agenda 21").

During this process earth scientists have reinterpreted the relationships between the various sub disciplines and their mode of inquiry. These changes are documented in the "Bretherton report" by the Earth System Sciences Committee (1988) which represents various American government agencies. Earth System Science (ESS) has now become the model for much of earth science research carried out in the USA, Germany (Emmermann, 1999) and many other countries. Today earth scientists focus on the System Earth and study the planet Earth in interdisciplinary, international teams. The results provide an important knowledge base about the Earth's history, present state and its possible future development. This is a necessary prerequisit to making responsible decisions about the use of the Earth's resources, avoidance of natural hazards, and maintenance of the Earth as a habitat. Hence, Mayer and Tokuyama (2002) regard knowledge about earth science issues as being part of scientific literacy. For this kind of scientific literacy they have coined the term earth literacy (Mayer 1995, 1997).

Earth sciences have become a school subject in middle and high school in many countries. To take account of the system view of the discipline Mayer and Fortner (Fortner et al., 1992; Mayer, 1995; Mayer and Fortner, 1995) developed a concept of Earth Systems Education (ESE). A variety of teaching materials for integrated science classes are available in the USA (Fortner 1991; Fortner and Mayer, 1993; Fortner and Mayer, 1993; Miller and Sheaffer 1995). However, in Gemany, secondary science education is divided into disciplinary biology, chemistry and physics curricula, while earth sciences are not a subject in school. Instead, geography education is offered, which considers earth science topics in its physical aspects. In the past decades it has taken an emphasis on socio-geographical issues. The lack of a coherent earth science education contrasts to the increasing demand of

society to teach students about global earth science issues, their chances and dangers.

In 2000, project "System Earth" started in Germany as an effort to introduce ESE to secondary science education. It aims at carrying out research on teaching and learning in the field as well as developing teaching materials that focus on an understanding of the System Earth with its interacting subsystems. The educational argument is to stimulate a rational discourse on issues of planet Earth. This discourse needs a well founded scientific knowledge. Four thematic areas provide a framework for the development of teaching materials. They are developed in co-operation with science and geography teachers, researchers in science education and earth scientists. The develoment work focussed during the first project phase on upper secondary education. In addition research on students' preconceptions of the System Earth and students' interests in earth science issues is being carried out and the results will be considered in the development work. The materials shall foster an interdisciplinary approach for teaching and learning. However, integrated approaches are not common in German upper secondary science education. Therefore the interdisiplinary material will be used in biology, chemistry, geography and physics courses. Nevertheless an interdisciplinary cooperation between the teachers shall be encouraged and can be realized in project courses. The material will be evaluated and revised. An implementation strategy is going to be developed.

The project "System Earth" established a three step approach to achieve its goals:

- Subject matter analysis: Based on the scientific framework a subject matter analysis was conducted in cooperation with earth scientists and science educators.
- Educational framework: A system of basic concepts, system theory and teaching methods for the development of pilot teaching material was established.
- Empirical research: Analysis of students' conceptions, students' interests and the process of implementation is being carried out.

In this chapter the three steps of the German approach to implement ESE will be described and exemplary pilot teaching material presented.

2. SUBJECT MATTER ANALYSIS

Earth sciences are the study of the System Earth, the study of the processes taking place within the Earth and at its surface, which in particular influence the reactions between the subsystems of atmosphere, lithosphere, hydrosphere and biosphere. Research into the System Earth draws on the methods of chemistry, biology and physics, on different scales of time and magnitude: from global observation of the planet from space to the analysis of crystal lattices at the level of the atom, and from the geological ages in the formation of mountain ranges (millions of years) to the rapid fracturing processes during earthquakes (microseconds). In line with this diversity, a wide range of methods and techniques is employed, including satellites

and space-supported measuring systems, as well as high-resolution processes for geophysical research at extreme depths. The methods also include laboratory experiments in which, for example, the pressure and temperature conditions of the Earth's crust and mantle are simulated. The scientific exploration of our planet is pursued in order to "understand the System Earth in all its parts, to discern global changes, to quantify endogenous and exogenous processes with their interactions and, on the basis of this understanding of the system and its processes, to develop strategies for securing natural resources and sustainable exploitation, using space above and below ground, storing waste, judging climatic and environmental development as well as anthropogenic influence on this development, and for protection against natural catastrophes and the minimisation of their consequences" (Emmermann, 1999).

Taking these systemic aspects and modern research findings into account the following four thematical fields were selected in co-operation with 18 German earth science institutes and science educators.

Materials from **the thematic area 1 "The system earth and life: a complex dynamic system"** promote an understanding of the System Earth and lead into the complexity of the system as a whole. They take into account that complex systems consist of a large number of interrelated components and are frequently open to environmental influences. The material also considers that the mostly non-linear interaction of the components can generate new system properties which are hard to predict, but conform to certain general structuring principles. The structuring principles and the promotion of thought in complex systems are primarily accessed in a top-down approach which highlights examples of the relevant principles. The genesis of knowledge on the earth as a dynamic system is a further focus of topic selection. Thematic area 1 contains the modules: "Earth as a dynamic system"; "Development of life on earth"; "Views of the world through time".

Thematic area 2 "Element cycles" deals with substance cycles. The materials look at dynamic processes that are influenced by human activity, e.g. the removal of substances from and the emission of substances into natural systems. The concepts of exploitation and protection are central. This area includes modules on cycles of non-metallic substances (e.g. carbon) and heavy metals.

Thematic area 3 "Resources" deals with the exploitation and maintenance of food and energy sources. By removing minerals, energy sources and biomass from the earth's system, and by emitting waste, sewage and exhaust gases, humankind intervenes, often on a massive scale, in the natural metabolism of the planet, affecting its dynamics both inside and out. Working through the modules, the students should be able to address the issues associated with sustainable utilization of resources and waste disposal. Modules include "Securing natural resources as a foundation of social development"; "Exploitation of alternative energy sources" such as geothermic energy; "Soil as food source" and "The sea as food source".

Thematic area 4 "Natural disasters" deals with the causes of natural phenomena and the associated issues of public protection. The natural phenomena are also discussed in a cultural and historical context. Modules include "Earthquakes"; "Floods"; "Volcanic eruptions"; "Climate change"; "Natural

phenomena in a cultural and historical perspective".

3. EDUCATIONAL FRAME WORK

As biological, chemical and physical processes inside and on the surface of the Earth are to be explored, in Germany the three traditional school sciences biology, chemistry, and physics are the first obvious settings for this teaching. As spatial-descriptive aspects also play a significant role, geography is a further relevant subject. A comprehensive basic understanding of the system can only be built up, however, if the interaction between elements within the system is dealt with from various points of view, but within a shared interdisciplinary context. For this reason, the topic lends itself to an integrated teaching approach, which is quite within the scope of the regional curricula in Germany. In recent years, interdisciplinary courses have been promoted and supported at all levels. Major research projects focussing on the Earth as a highly complex system generally involve biologists, chemists, geologists and physicists, a fact which facilitates an interdisciplinary approach in teaching, particularly as the knowledge emerging from earth science research forms a coherent whole.

Basic to the project "System Earth" approach is to give a comprehensive understanding of the principles of the structure and function of our constantly changing planet and to provide a framework for a process-oriented understanding of the earth as a dynamic system. The concept of the project is an applied, interdisciplinary approach that weaves the basic concepts of earth sciences (Figure 1) and uses students' knowledge of biology, chemistry, and physics to study the nature and interactions of various topics of earth science s (e.g. CO_2/carbonate-system, rock cycle, greenhouse effect, climate change) and their impact upon people and the planet Earth. That means to understand the interaction of the various spheres and cycles of the earth with emphasis on positive and negative feedbacks.

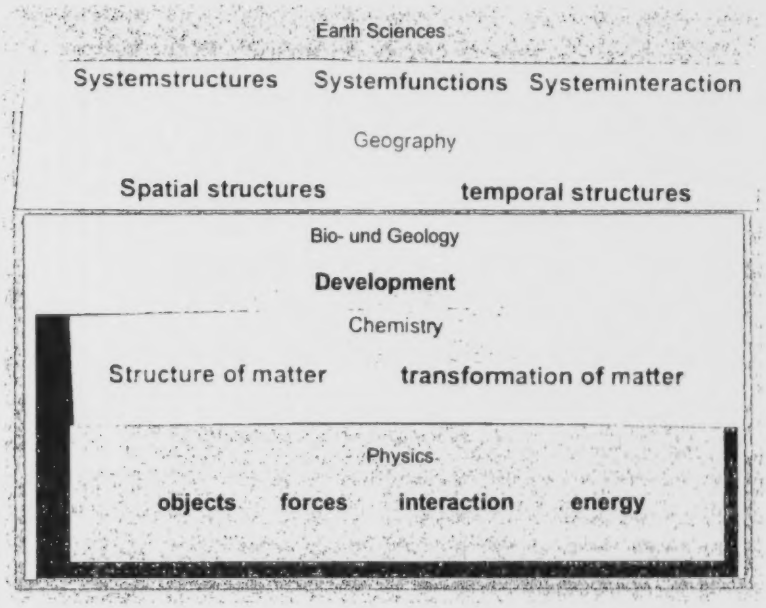

Fig 1. Basic concepts of biology, chemistry, geography, geology and earth sciences

On the other hand, topics concerning global change have become in our days part of the public debate about sustainable development. The project "System Earth" sets out to enable students to understand and, where appropriate, participate in the discourse. Competence in this case includes a basic understanding of what earth sciences have revealed about structure and function of our planet as a system and about the sustainable exploitation of its resources and the development of forecasting techniques and prevention strategies. Competence also includes the ability to conduct basic ethical analysis and to make critical, rational judgements. In addition, the students need to be able to make their own practical contribution to the debate and obtain relevant information on their own.

To inform about earth science contents as well as to train social and behavioural skills, teaching and learning have to be based on active learning methods. Hence, a variety of teaching methods are necessary to fullfill the project goals:

- Graphical representations (mind maps, concept maps) of information are used to externalize, to categorize and finally to visualize students' ideas and concepts of Planet Earth.
- Practical work and hands-on activities involve the students in a learning which requires the application of new methods and enhances their ability to think critically. The student is encouraged to plan a process, to test a hypothesis, put the process into motion and then be able to explain the attained results.
- Collaborative investigations or collaborative learning of earth science subject-matter enable Students to work in small groups and to be responsible for others'

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learning as well as their own. According to Johnson and Johnson (1986), there is evidence that cooperative teams retain information longer than students who work quietly as individuals. Using the experiences of Fortner (2002) for selected topics teaching material will enable teachers and students to carry out the form called "jig saw".

- Multimedia is implemented on various levels within the teaching material. First of all, the material will be provided in digital form to the teachers. They will be able to select and combine individual materials for their specific classroom needs. This supports the flexible, modular structure of the teaching material since many links between the subject matter analysis of the various submodules are possible. This represents the fact, that earth science issues are all related to each other. Furthermore material for a computer supported teaching will be provided.
- Complex and dynamic processes e.g. the climate system, the greenhouse effect or the carbon cycle, are very difficult to comprehend. However, in school simulation and modeling of selected aspects of the real Earth system is required for understanding how the complex systems change over time and how internal feedback loops within the structure of the system influence the entire system behavior. A simulation is the manipulation of a model in such a way that it operates in time or space to compress it, thus enabling one to perceive the interactions that would not otherwise be apparent because of their separation in time or space. The central concept of modeling is to understand how all the objects in a system interact with one another. From the interaction of the student and the models emerges an understanding of what makes sense and what doesn't. In this way, models are tools for summarizing knowledge, and extrapolation and evaluating of alternatives in planning. Together with learner-centered learning, modelling forces the learner to become actively involved.
- Computer animations, videos and transparencies are provided to enable teachers and students to give a presentation on selected aspects.
- To ensure the introduction of modern earth science research issues in schools even after the end of the project, structures for a dialogue between schools and research institutes will be established.

4. EMPIRICAL RESEARCH

4.1. German students' concepts of system earth

Conceptual knowledge of the earth and its subsystem is both a condition and an outcome of Earth Systems Education. To assess German students' concepts of system earth we have developed an association test. It was based on 167 secondary school students without prior instruction in earth systems education. Each student was asked to write down up to 10 terms or brief ideas that they associated with "system earth". For this task they were allowed 10 minutes. A content analysis of the verbal data guided by system thinking ideas, geological and scientific considerations and the role of humans within system earth, was carried out. It provided a sheme of 59 categories that we used to analyse the students' responses.

The categories were the atmosphere, the biosphere, the lithosphere, and the hydrosphere. Moreover it included terms presenting the universe, the physics and the chemistry of the earth, natural phenomena, systemic features of the earth, and three areas of the anthrosphere (science, technology and learning; actions guided by human values; socio-cultural context). Within each sphere we also categorized three systemic features (presented as the subcategories: static objects, dynamic processes, and relations among subsystems of the earth; see Hansen & Hlawatsch, 2003). In this chapter we present main trends of our study by a reduced scheme of 8 principal categories. We left out the different subcategories of the complete scheme. Figure 2 shows the percentage of terms in each category:

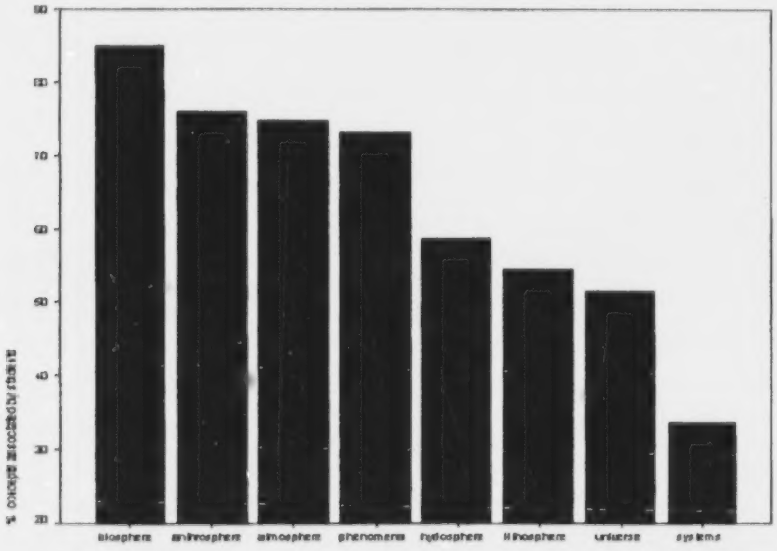

Figure 2: Percentage of terms students associated with "system earth" categorized by one of the 8 main categories

A comparison of the percentages indicates that almost 90 % of students wrote down concepts that could be categorised as examples of the biosphere. More than 70% of students also wrote down terms that were categorized as examples of the anthrosphere, atmosphere or natural phenomena. Terms related to general system categories were the smallest category. What do these percentages tell us? Considering that only about 50 % of the students wrote down terms belonging to the lithosphere we conclude that about half of the students did not consider all of the spheres when associating concepts of system earth. Furthermore only about 10 % of terms in each category are on a "relational level" that directly presents relationships among subsystems. From these observations we conclude that schools need a teaching material that helps students to understand system earth as being composed of its essential subsystems and the dynamic processes among them.

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4.2. German students' system thinking

A further empirical study looked at the students' system thinking in the special field of the global carbon cycle (Hildebrandt and Bayrhuber, 2002, Bayrhuber et al. 2002) rather than for their general conceptions of the System Earth. This study used interview data of five secondary school students aged 16 to 18 years. The analysis of students' preconceptions of the carbon cycle was done by half structured interviews (45 minutes), drawings (10 minutes) and a questionnaire (20 minutes).

The global carbon cycle represents a complex system combining biological, chemical, geological and physical processes and serves as an ideal model to illustrate the interactions between the earth's subsystems, such as the atmosphere, the hydrosphere, the lithosphere and the biosphere. The study focuses on the characteristic properties of this natural system. The interest is directed towards permanently changing non-linear, irreversible and cyclic processes. The interviews revealed that students perceive these dimensions of system thinking only fragmentary. For the analysis of the results three dynamic dimensions according to Ossimitz (2000) have been chosen: the ability to identify the *elements* of a system, the *relations* between the elements and the *properties* of the a system as a whole.

On a general level first results show that the students do not identify the relevant *elements* of the carbon cycle system. In addition, they do not estimate the global distribution of carbon in a realistic order of magnitude. For example they vastly overestimate the atmosphere and the biosphere as reservoirs of carbon in relation to the lithosphere (rocks) and the hydrosphere (ocean). Furthermore the students have problems to realize the transport of carbon as a *cycle process*. Some of them describe it as a *linear process* between the lithosphere and the atmosphere. In this connection the lithosphere is considered as an inexhaustible source and the atmosphere as an unlimited sink of carbon. In some cases the students describe a *cycle process* but they reduce it to the *relations* between the *elements* plants and animals, or the *elements* photosynthesis and respiration. In this connection they regard only two *elements* of the carbon cycle system (biosphere, atmosphere) and not the *interrelationships* of all earths' spheres. Moreover the students do not consider the carbon cycle as a permanently changing system. The students have problems to realize the *dynamic properties*, such as non-linearity and irreversibility, which have determined the transformation of the carbon cycle in the course of earth's history. They explain the developement of the earth in terms of linear processes. However, the five students identified a change of the carbon cycle system, which is only observable on a historical time scale. Maybe students do not distinguish individual experiences of the earth as a practically stable system during their lifetime and scientific findings on the history of the earth. Further analysis shall show if there exists a fragmentation of knowledge.

4.3. German students' interest in earth science issues

From an educational point of view, interest is an important precondition for learning (e.g. Todt 1978; Prenzel, Krapp and Schiefele 1986). Empirical studies indicate, that

learning in an interesting manner results in higher order learning strategies (e.g. Hidi and Andersen 1992). The knowledge is elaborate and longer lasting. In this sense we understand data about students' interest as fundamental for the development of teaching materials and the evaluation of teaching effects.

Interest can be differentiated in individual and situate interest. While individual interest is seen as an enduring personal disposition to engage with a special area, situational interest is seen as a short-term interest in certain topics produced by an interesting situation. Häußler and Hoffmann (1998) argue that lasting, individual interest develops out of situational interest. They distinguish three dimensions of situation-related interest: interest in a specific item, interest in a specific context connected with the content, and interest in a specific learning activity to pursue context-bound content. On the base of this work of Häußler and Hoffmann (1998) a questionnaire was developed for a pilot study. 333 students grade 11 to 13 and administered in three German *Laender* (states) (Bavaria, North Rhine-Westphalia, Schleswig-Holstein) to a total of 162 female students and 171 male students (Bayrhuber et al., 2002). The first part of questionnaire comprised 88 items in a systematic combination of 11 fields and eight contexts. The topics were subsystems of the earth, carbon cycle, rocks and minerals, fossil resources, soil, gas hydrates,ocean, drinking water, earth quakes, climate changes, changes in biodiverity. The contexts comprised individual concern, significance for society, social responsibility, earth as complex and dynamic system, earth science research, earth history, regions of the earth, methods of earth sciences. In a second part the topics and contexts are arranged to find out if students find the topic interesting in a disciplinary presentation or if they would prefer system orientated presentation. Data about the students' interest in various activities was obtained separately. In addition, the students were questioned about their school and out-of-school activities involving earth science topics.

On a general level, first results show on average a medium interest in almost all contents. The lowest interest in rocks and Minerals and a relatively high interest in Earthquakes. For about half the topics, there were no gender differences. But females showed on average a significantly stronger interest than males in soil, drinking wter, earthquakes and changes in biodiversity. Males, on the other hand were on average significantly more interested in fossils, natural resources and gas hydrates.

The study suggests that the interest in the topics is situational, induced by the items of the questionaire rather than a stable individual interest. Concerning the activities the students expressed a relatively high level of interest in the passive acquisition of information (listening to a lecture, looking at pictures, watching a video) and in practical learning approaches, such as earth science experiments and data collection on field trips. The interest expressed by students in the various subject-oriented aspects correlates positively with the frequency of coverage. They showed significantly more interest in the biology and geography related aspects than in the chemistry and physics related aspects.

5. PILOT TEACHING MATERIAL

In collaboration with German earth science research institutes and qualified teachers, teaching materials were developed in an iterative, participatory design approach. The materials display a modular structure and could be applied in biology, chemistry, geography and physics classes. They encourage interdisciplinary co-operation and the use in interdisciplinary special courses. Clearly indicated relations of the individual issues to all other units of the project ensure the flexible modular structure. This allows easily to continue with all other modules and aspects of the earth system. The modules for the upper secondary grades:

- System Earth - an Introduction
- The Climate System and the History of Climate Change
- Matter Cycles
- Resources and Recycling
- Convection in Atmosphere, Hydrosphere and Lithosphere
- The Rock Cycle: Documents of the Earths' History
- Tides and Waves
- Working in Earth Sciences
- Origin and Development of Life
- The Watercycle and the Protection of Drinking Water
- Chemistry and Physics of the Atmosphere
- Plate tectonics and Volcanism
- Earthquakes and Waves: Information about the Earths' Interior

The materials are provided in stages of graded difficulties. For each module a subject matter analysis on recent research was carried out in cooperation with earth scientists, science educators and teachers and has been compiled for the teachers background information. An introduction gives the basal knowlegde of the topic and its importance for the earth and the human society an can be taught by from all science and geography teachers. Additional specific knowledege for intensive courses focus on special biological, chemical, geographic or physical knowledge within an earth science context. Suggestions for the classroom use is given and a complete set of teaching material including lectures, exercises and interactive digital units are provided. The information will be available in digital form on CD-ROM or via the world wide web. However, for each module a text is available as file wich can be printed.

The system approach is mainly implemented through the organizing scheme of the four major subsystems of the earth (atmosphere, biosphere, hydrosphere, lithosphere). An emphasis is on the development of material to issues which emphazise the meaning of the interaction of the four spheres for the functioning and the development of the earth--e. g. climate system, rock cycle, carbon cycle, convection as driving force.

To provide a systemic framework which this knowledge can be built upon, an introduction unit has been developed. This introduces the sub systems atmosphere, biosphere, hydrosphere and lithosphere, their specific features and the milestones of development of System Earth since its origin 4.6 billion years ago. The unit comprises 3 – 4 lessons and provides material to introduce briefly into the

system theory aided by a set of overheads. It then allows the students to carry out concept mapping to externalize and categorize their pre conceptions of the System Earth. At last a computer based quiz on the milestones of earth development fills in missing knowledge. These introductory materials provide a phenomenon-focussed access to the concept of the System Earth. They are primarily designed as motivational and organizational aids, offering an overall view to raise interest, inviting wonder and empathy, an affective bond with the subject. The intention is to show that our own existence and that of life in general depends on the earth being the way it is, and that the system can be profoundly influenced by human intervention.

6. CONCLUSION

A concept to introduce modern earth science research issues into German secondary science and geography education was developed. The base was a framework of earth science issues collected in co-operation with 18 German earth science institutes and science educators. From this framework a module list was constructed. This module list was discussed with teachers and a strategy for the development of teaching material on the base of explorative studies on students perceptions and interests of the Earth system was derived. Deficits between the theoretical claims of the project and the reality became obvious. To full fill the special needs pilot teaching materials on the dynamic of the earth and an introductory unit were developed which is expected to shows positive effects on students higher order system thinking. Seven of the total planed thirteen modules are currently tested in schools all over Germany.

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CHAPTER 12: EARTH SYSTEMS EDUCATION AND GLOBAL SCIENCE LITERACY: THE SINGAPORE EXPERIENCE

Leo Tan Wee Hin and R. Subramaniam, National Institute of Education, Nanyang Technological University, SINGAPORE

1. INTRODUCTION

Traditional school science curricula place heavy emphasis on the physical sciences and some emphasis on the life sciences, not surprisingly since the fundamental concepts inherent in these sciences have been shown to provide a technological dimension for economic development, in the process fermenting a renaissance that has led to the proliferation of industrial societies in many countries. The disciplinary orientation in which these curricula are developed has given rise to a reduction approach in the treatment of science, especially at the higher levels. This is widely perceived to come in the way of promoting an integrated perspective in the teaching and learning of science, even though there is general recognition that these attempts are approaches that have helped to rationalize the workings of science in pedagogically convenient and interesting ways.

In recent times, there have been calls for integrated science curricula to be taught in schools. Extant in this debate is the recognition that the workings of science can be simplified further to foster cognitive gains and instructional simplification. In an integrated curriculum, tremendous scope is offered for harnessing the synergies arising from the diversity and creativity of content. Besides offering scope for addressing the alienation of students from traditional curriculum subjects, an integrated focus also permits students to make links across and beyond the curriculum, presents a vehicle to foster thinking attributes, furnishes a platform for creating, and provides a language for communication (Bean, 1991 and Kleinman, 1991). Since not all students would be able to study the various scientific disciplines in the school setting, a segmented approach comes in the way of achieving a holistic level of science literacy or, worse still, a fissured scientific knowledge base.

The National Research Council in the USA has established National Science Education Standards, which calls for an approach that provides less emphasis on studying discipline-oriented content and more emphasis on integrating all aspects of science (National Research Council, 1996). In a report entitled Beyond 2000, compiled by British science educators (Millar and Osborne, 1998), there have also been calls for integrating the disparate elements of the science curricula into a coherent format. In the context of the foregoing, Earth Systems Education (ESE) and systems science methods are emerging as candidates for the organization and integration of curricular content in science, mainly through the seminal contributions of Mayer (Mayer, et al, 1995, 1997, 1998 and 1999, and 2002) Within a holistic framework, Mayer stresses that such approaches will be able to demonstrate to students how fundamental processes operate within systems and how these systems change as a result of human intervention, thus providing a basis for Global Science Literacy (GSL). Indeed, integration blurs the boundaries of the perceived mutually exclusive zones mapped by the traditional disciplines.

In the ESE approach, content is organized conceptually rather than by discipline. By referring to the earth system and its processes as the organizing framework, a variety of concepts in physics, chemistry and biology can be taught. An advantage of such an approach is that it fosters a relational perspective in the context of the natural environment around us, and thus makes learning more meaningful and conceptually engaging to students. Indeed, research has shown that pupils can memorize, comprehend and learn things more easily in the context that is meaningful and interesting to them (Ivan-Nejad, Mckeachie and Berliner, 1990).

The framework for ESE is based on a series of seven understandings around which it is possible to build a consensus for integrating content in science (Mayer, 1995).

The purpose of this chapter is two fold:

1. to look at important similarities between the science/geography curricula in secondary schools in Singapore and the tenets of the GSL, especially those that are fundamental to GSL and that are significantly demonstrated, as well as highlight any dramatic differences, and
2. to assess the potential for incorporation of further GSL elements in the science/geography curricula.

2. REVIEW OF EDUCATION SYSTEM IN SINGAPORE

We review briefly in this section the salient aspects of the education system in Singapore so that the ensuing discussion can be better appreciated in context.

In Singapore, there are three stages in the formal education process: primary education of six years (Ages 7-12), secondary education of four or five years (Ages 13-16/17), and post-secondary education of two years (Ages 17/18 - 18/19). Figure 1 illustrates the relationships between these various stages.

As Singapore is a small nation (land area of about 30 km by 25 km) with a heterogeneous population mix, educational reform has focused more on optimizing the use of its limited human resources (4 million people) as well as placing emphasis on the use of science and technology to overcome various constraints, thus maximizing the relevance of Singapore in the global economic arena. Among the important policy initiatives that have been instituted to realize these objectives in the education field include:

- Streaming of students after Primary 4 examinations, that is, placement of pupils in three different streams at Primary 5 according to their academic results
- Streaming of students at secondary level according to the results of their Primary 6 examinations into four steams: Special, Express, Normal Academic and Normal Technical. Students in the Special and Express streams cover the secondary education in four years while those in the Normal and Technical streams cover it in five years. Students in all four streams pursue a common curriculum in the first two years. After this, they follow a prescribed curriculum comprising a core mix of subjects plus various electives according to the streams they are in.
- Emphasis on English as the medium of instruction in all subjects except mother tongue

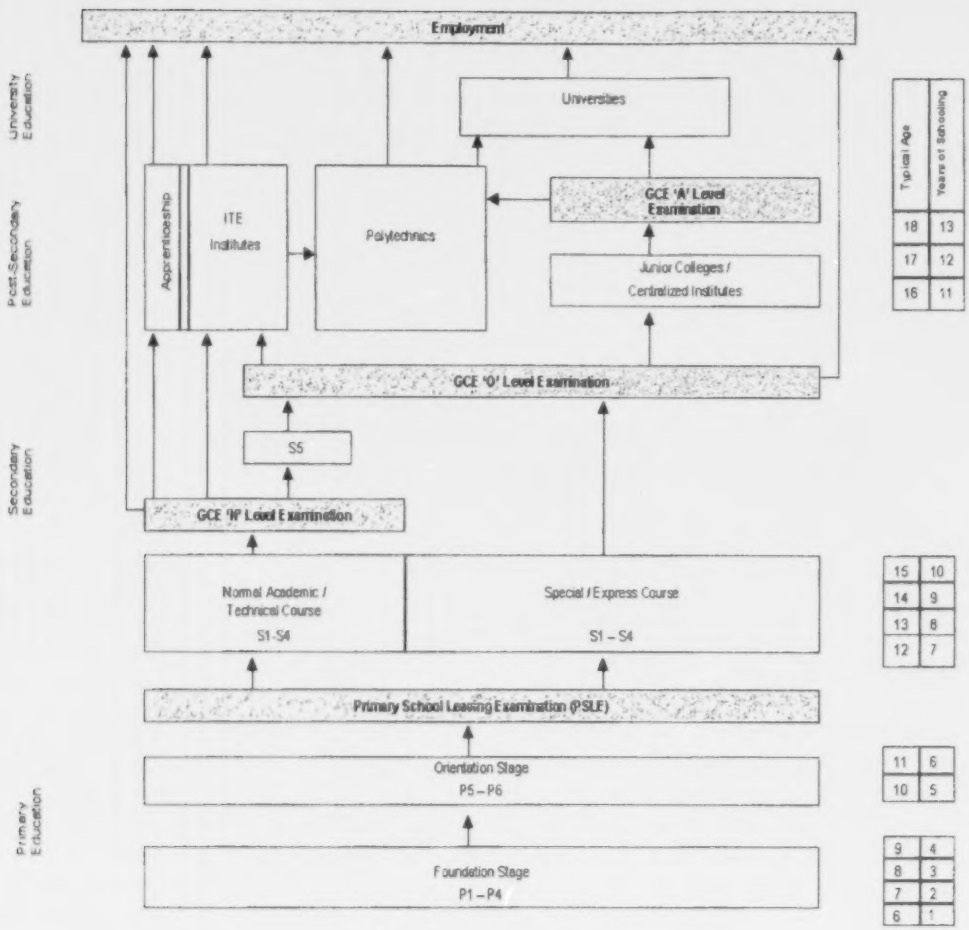

Figure 1 Flow Chart of Singapore Education System

- Multi-route system to the university so that slow learners will also have an opportunity to make it to tertiary education in due course

Streaming was introduced at primary and secondary levels on the grounds that a single curriculum of six years of primary education, four years of secondary education and two years of pre-university education, in which all students, irrespective of ability and rate of learning were required to follow the same syllabus at the same place and sit for the same public examinations, failed to take into consideration the variations in learning and absorptive capacities of the students (Yip, Eng and Yap, 1999).

Singapore's rapid economic development has been a key factor that imposed additional pressures on the education system to ensure that it embraces best

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practices, and that content taught is relevant as well as current. In this context, exemplary practices in other parts of the world, especially in the USA and Europe, are closely followed to see how these could be best adapted to local needs. Also, special initiatives necessitated by the uniqueness of Singapore's geopolitical position and pluralistic societies have been introduced in the education system. The concatenation of the foregoing factors has resulted in an emphasis on outcome-based education so that the deliverables can be quantified in good measure.

Reform in science education has been especially significant. This has been underpinned by Singapore's unique geographic position as well as the need to address certain social, political and economic needs. This sets the basis for mapping the general terrain of the curricular structure so that the underlying discrete elements can be developed with a good degree of flexibility within the framework prescribed. Over the years, there has been regular adding and deleting of content in the curricula, ordering in hierarchy of priorities for content delivery, and incorporation of project work in the curriculum on an assessment basis. Attributes of creative thinking, critical thinking and problem-solving skills are infused in the lessons. The use of information technology in the lessons is pervasive. A major development was the decision in 1978 to discard the age-old General Science curriculum, which taught science as three separate subjects, namely, physics, chemistry and biology. This has led to the Lower Secondary Science program, which sets out to organize and integrate the three science subjects around a set of five basic themes: Exploring Science, Structure of Matter, Water and Solution, Energy and Life, and Ecology (Ang and Yeoh, 1997). Later on, the concept base in science was themed along five strands on an integrated basis; diversity, cycles, interactions, energy, models and systems, and measurements. A major reason for this choice of themes is that they significantly allow for the teaching of content in an integrated manner and in the context of the natural world around us. Subsumed in this understanding is the recognition that earth system education processes, among others, provide a useful basis for teaching content that is conceptually relevant to students. An initiative introduced in 1997 was on National Education - this is to ensure that students are also cognizant of the geopolitical realities in relation to Singapore's size and position.

The presence of the Ability-Driven Education in Singapore has been a key factor in ensuring that its limited human resources are put to optimal use and that the attrition rate among a batch of cohorts is minimized dramatically. As a result, almost 100% of students become eligible for secondary school enrollment with at least 70% now having at least 5 'O' level passes. Figure 2 charts the enrollments in higher education institutions (Ministry of Education, 2000).

All schools in Singapore place significant emphasis on informal science education such as visits to science centers (Tan and Subramaniam, 1998), and have good linkages with scientific societies (Tan and Subramaniam, 1999). Since 2000, all schools have been wired up for broadband access to the Internet (Tan and Subramaniam, 2000).

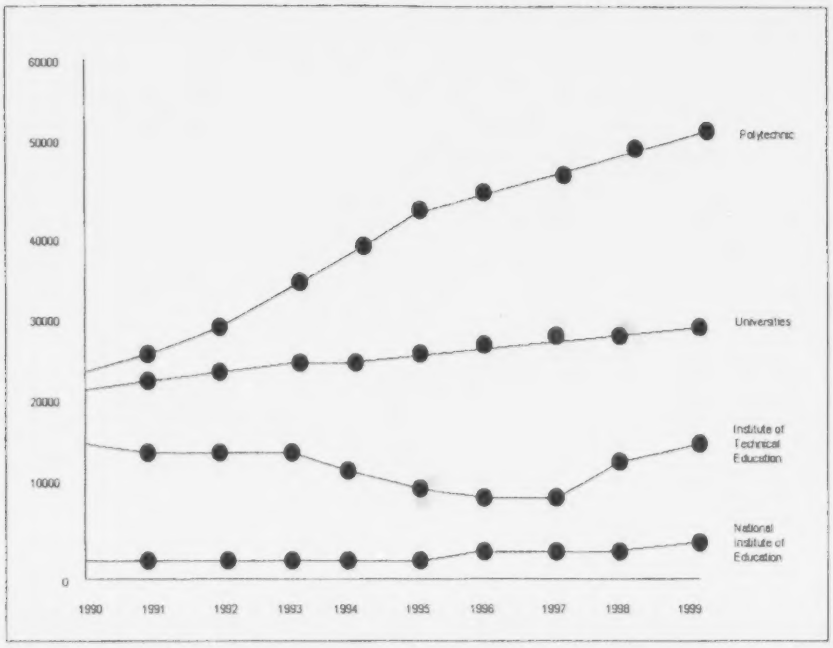

Figure 2. Enrollments in Higher Education Institutions

The central authority for all educational policies is the Ministry of Education, and all schools come under its purview. Professional training of teachers is conducted by the National Institute of Education, an institute of the Nanyang Technological University.

3. ELEMENTS OF ESE INITIATIVES IN GEOGRAPHY AT LOWER SECONDARY LEVEL

The syllabus for geography is a refinement of the 1995 syllabus. It continues with the physical-human interaction as its central theme. In addition, it has integrated three initiatives in both teaching and learning: thinking skills, information technology and national education. Whilst the syllabus provides a general framework for the development of the curriculum, teachers are encouraged to infuse current issues and events to make the subject lively and interesting. The general aims of the subject are as follows:

- to stimulate pupils' interest in geography
- to provide a holistic understanding of physical-human relationships

- to develop basic skills in acquiring, communicating and applying geographical knowledge
- to develop an informed concern about the quality of the environment and the future of the human habitat, and thereby enhance pupils' sense of responsibility for the care of the environment

These aims are in broad agreement with the GSL philosophy. Examining the specific objectives of the subject matter with respect to acquisition of knowledge, skills and attitudes, and values, there is again a significant reflection of the GSL philosophy, as can be seen from most of the following propositions framed in the syllabus:

Knowledge

--to acquire knowledge on the components of physical and human landscapes
--to acquire an understanding of physical-human relationship at local, regional and global levels
--to acquire an understanding of Singapore's strategic vulnerabilities and constraints, and the strategies used to overcome them

Skills

--to develop skills in the identification and classification of physical and human features of the landscape
--to develop skills involving the observation, collection and recording of geographical information in the field
--to develop skills in the interpretation and analysis of maps, tables, graphs, photographs and field work data
--to develop skills in the use of IT in a relevant and useful way

Attitudes and Values

--to inculcate a sense of appreciation and responsibility for the quality of the environment at local, regional and global levels
--to develop an empathy for and a sensitivity towards people in different landscapes
--to develop an instinct for survival and confidence in the future of Singapore

A systematic framework is adopted to organize content in the syllabus. Four themes are covered in Secondary 1:

1. Introduction to geography
2. Landscapes
3. Components of physical landscapes
4. Components of human landscapes

and another four themes are covered in Secondary 2:

5. Human role in changing earth's surface - positive impact
6. Human role in changing earth's surface - negative impact
7. Natural resources
8. Earth as our habitat

For each of the themes, specific content, learning outcomes and values/attitudes that need to be addressed by the teacher are prescribed.

The extent to which each of the eight themes in the subject of geography at lower secondary level is consistent with the GSL philosophy is now addressed:

- For Theme 1, curricular content focuses on four topics: Earth as part of the solar system, only one Earth and one home for all mankind, fragile nature of Earth as an entity, and spatial patterns of continents, oceans and countries that make up the Earth. The first topic is cognizant of Understanding 6 for it stresses the co-ordinates system of the Earth with respect to the Sun in the Solar System, and emphasizes that it is the only hospitable planet for the support of life-systems. It further reiterates the point that Earth is a spaceship cruising through outer space and that, as it does so, it rotates on its axis and revolves around the Sun, thus giving rise to the day-night duality and the four seasons. The second and third topics are clearly reflective of Understanding 1 for the content emphasizes the uniqueness of our blue planet as well as underscores the great value it has for mankind on account of its delicate ecosystems -- thus making it incumbent on humanity to promote responsible stewardship of the interacting subsystems which it supports. For the fourth topic, content focuses on how plate tectonics has shaped the distribution of landmasses and given rise to the geographical features that manifest on the earth's surface -- a reiterating of one of the six components of Understanding 4.
- For Theme 2, the main concepts that are taught include physical landscape, human landscape, physical-human relationship, interdependence, and map-reading skills. The points that sought to be inculcated among students are that all physical landscapes are subsystems that arise from plate tectonics and that they are subject to change through natural processes and cycles -- reflective of two of the components of Understanding 4, and that human interaction has given rise to settlements which can impinge on the stability of other subsystems -- a reinforcement of one of the six components of Understanding 4. Though the emphasis on map-reading skills is required in the syllabus, and it does not find specific support in any of the seven understandings of ESE, it can be broadly subsumed in Understanding 7 -- after all, mapping the terrestrial terrain is a result of the study of certain aspects of the Earth through precise scientific methodologies.
- For Theme 3, curricular content focuses on weather and climate, natural vegetation, water, and rocks and landforms. The importances of these components in physical-human relationship as well as the inter-relationship of all four physical components are also explored. This theme is a development of some of the sub-aspects of Understanding 4. The role of the Sun as a source of energy that drives climatic subsystems is reinforced through concepts such as heat, cold, evaporation, condensation, temperature, rainfall and wind. Also, its mediation of climate-vegetation relationship is developed in the topic of natural vegetation. A case study of the tropical rainforest in Singapore, the largest located in any city in the world, is added to provide an indigenous flavor as well as to reiterate the need for conservation efforts. This is central to preserving the sanctity of the ecosystem, a reinforcement of one of the premises of Understanding 4 -

- that the presence of life affects the characteristics of other systems. The role of the Sun in driving the hydrological cycle is further developed in the topic of water as well as in the interacting subsystems nucleating around water, for example, transpiration, energy from flowing water, and so on. The forces, motions and energy transformations that drive the interactions within and between these subsystems -- one of the premises of Understanding 4, is further developed through concepts such as ocean currents, run-off, and power of rivers in creating features in landscapes. The influence of the moon in giving rise to tides is another concept which is covered here – reminiscent of a postulate of Understanding 6. Concerning the topic of rocks and landforms, again the role of plate tectonics --one of the premises of Understanding 4, in generating such features is developed through ideas such as volcanoes, mountains, rift valleys, and other diverse landforms and rock forms. The influence of internal forces in crustal movements giving rise to landforms as well as how these are shaped by external forces of denudation – reflective of a few postulates of Understanding 4, are also covered in detail in this section. One of the postulates of Understanding 5, that materials making up the planet have been recycled many times, is tellingly demonstrated in the case of water by reference to the hydrological cycle.

- For Theme 4, curricular content is restricted to population and settlements, food production, and natural resources. That the development of scientific thinking and technology increases man's ability to understand and use Earth judiciously - aspects of Understanding 3, is explored here. For example, human landscape is shown to be the product of the interaction of technology with the physical components, marrying of scientific ways with agricultural practices is shown to increase food production, mining of natural resources is shown to lead to a proliferation of diverse applications, patterns of settlements found in different types of environments are shown to be indicative of man's ingenuity in taming nature, etc are all broadly reflective of this line of thinking.
- For Theme 5, curricular components focus on how the ingenuity of man has made possible the overcoming of various constraints – land reclamation, making of lands arable, and promoting of accessibility via transportation. All these are broadly reflective of the correlation between the development of scientific thinking and technology, and our ability to understand and utilize Earth – Understanding 3. The concepts of evolution and fossils are, however, not addressed.
- For Theme 6, curricular content looks at three topics: causes and symptoms of an ailing earth - population increase, land clearance, technological changes due to industrialization, and human consumption patterns; pollution, as manifested through acid rain, deteriorating air quality, toxic wastes, oil spills and waste disposal problems; and global environmental changes arising from increased carbon dioxide levels, increasing global temperatures, depletion of ozone layer, and sea level changes. The role of humankind in precipitating these problems is underscored as well as the

need for individuals to develop a sense of responsibility for the quality of the environment. These are all well aligned with Understanding 2 of the GSL philosophy.

- In Theme 7, Understanding 3 is further developed through content which focuses further on how the spirit of scientific enterprise has made possible the development of technology for the mining and use of natural resources as well as usage of the environment. A reiteration of the point that recycling of materials is common in nature, a postulate of Understanding 5, is reflected in the section on renewable resources – air, forest and water, in contrast to non-renewable resources such as fossil fuels. A local context is also embedded for better appreciation – how Singapore with its limited land area has judiciously used ingenious measures and technologies to increase its land area through reclamation as well as augment its water resources through construction of elaborate conduits to channel precipitation from outlying areas in order to enhance the catchment capacity of the reservoirs, as well as by getting water through treatment of effluent. An appreciation of the need for prudent use of natural resources is one of the desired values/attitudes goals in this section – aspects of Understanding 2. .
- For Theme 8, an exhortation on resource conservation using a tripartite approach involving the individual, the region and the international community is developed. Through these efforts, a sense of responsibility is sought to be inculcated among students for the quality of the environment and the future of the Earth --altruistic aims, no doubt, and which reflect broadly the aims of Understandings 1 and 2.

In respect of the weighting of GSL elements, we estimate that it is about 70 %. The basis for this estimate is shown in Table 1.

Table 1. Estimate of Percentage of ESE Elements in Geography

Understanding of ESE	**Number of attributes covered for each of the Understandings of ESE as a function of the total number of attributes**	**%**
1	2 out of 3	66.7
2	5 out of 5	100.0
3	4 out of 6	66.7
4	6 out of 6	100.0
5	2 out of 4	50.0
6	5 out of 6	83.3
7	2 out of 5	40.0

Average % = 506.7/7 = 72.4 %

This high weighting is an important contribution to the current debate on fostering Global Science Literacy through ESE elements.

Of interest to note is the significant amount of science covered in the context of earth sub-systems - for example, technologies used for land reclamation, factors contributing to increased crop yields, pollution, acid rain, ozone hole depletion, global warming, renewable/non-renewable resources, water, etc. The use

of an indigenous focus in many of the lesson modules further contributes towards promoting an integrated perspective of various issues as well as help link content to practice. By accentuating the emphasis on the natural environment as well as highlighting the humanistic dimension impinging on it, the curricular modules strive for the inculcation of attributes that are consistent with an appreciation for nature and the need to promote responsible eco-citizenry, again mirroring the basic spirit of the GSL philosophy. In fact, the subject of geography can well be considered as Earth Systems Education because of its pronounced focus on physical-human interaction.

It can thus be inferred that the syllabus of geography at lower secondary level broadly subscribes to the seven understandings of ESE, even though the content and concepts are not grouped under the general theme of ESE. Obviously, by formatting the existing content on the basis of the seven understandings of GSL there would be a better fit.

4. ELEMENTS OF ESE IN THE SUBJECT OF SCIENCE AT LOWER SECONDARY LEVEL

The syllabus of science at lower secondary level is essentially a continuation of the primary science syllabus. It seeks to develop the scientific base further and in greater depth. Curricular content has been structured in such a way that it serves as a bridge to, and as a foundation for, the pursuit of science at a higher level.

The topics in the physical and life sciences are organized into six main themes for the development of content:

- Diversity
- Cycles
- Energy
- Interactions
- Models and Systems
- Measurements

A multiplicity of topics in the physical and life sciences are covered in each theme in an integrated manner without emphasizing the disciplinary underpinnings inherent in the concept base. Especially, the first five themes present enormous scope for emphasizing the harmony and unison that prevail in various earth sub-systems – clear identification with GSL tenets. This is an important criterion for promoting a worldview of responsible citizenry.

An inquiry theme is used by teachers to weave the desired skills, processes and attitudes when teaching. The subject material is developed within each thematic area by linking content to the natural world - good curricular design according to GSL philosophy.

Among the aims propositioned in the syllabus for the inculcation of scientific literacy among students, the following are in consonance with the general spirit of the GSL philosophy:

- stimulate interest in, and care for, the environment

- develop attributes relevant to the study and /or practice of science -- for example, objectivity, inquisitiveness, integrity, etc
- promote an awareness that the applications of science are generally beneficial, but the abuse of scientific knowledge can be detrimental
- that the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, educational and cultural influences and limitations
- stimulate curiosity, interest and engagement in science and its methods of inquiry
- develop abilities and skills that are relevant to the study and practice of science, and that are useful in everyday life.

The exhortation given to teachers to promote understanding of science by leveraging on the primacy of the pupil's world is clearly identified with GSL. An overview of the topics by level is presented in Figure 3.

	Science as an Inquiry	**Measurement**	**Diversity**	**Models and Systems**	**Interactions**	**Energy**
Sec 1	Science and technology. Attitudes. Science process skills.	Use of measuring instruments Physical quantities and units	Classification of matter Classification of plant and animal life. Elements, compounds and mixtures. Solutions and suspensions.	Cells-structure, function and organization	Forces and its related concepts. Effects of heat. Transmission of heat. Abuse to life processes	Sources of energy and storage of energy Photosynthesis and respiration
Sec 2	**Science as an Inquiry** Science and technology Attitudes Science process skills	**Cycles** Nutrient cycles in the ecosystem		**Models and Systems** Particulate model of matter. Simple concepts of atoms and molecules. Transport in living organisms. Digestion in animals. Sexual reproduction in human beings.	**Interactions** Chemical changes. Sound. Simple concepts of population community and ecosystem. Energy transfer processes in the ecosystem	**Energy** Light Electricity

Figure 3 Overview of Topics at Lower Secondary Level

The curricular design shows that an integrated approach, in contradistinction to the disciplinary mode, is used to develop content. This is

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recognition that the disparate disciplines do admit of a number of natural linkages and overlaps that allow for them to be bannered under a generic label. The good design ensures that pupils can make connections to the content learned in the context of the natural world around them. Emphasis is placed on reiterating the stance that none of the processes covered in the various themes occur in isolation or in a strictly reduction setting – goals clearly identified with GSL philosophy.

An appraisal of the curricula in the context of ESE elements with respect to the framework presented in Figure 3 is now presented:

- Understanding 1 is not covered explicitly but is indirectly reiterated. For example, one of the postulates here – that a better understanding of its sub-systems enhances human appreciation of Earth, is broadly circumscribed in the themes of interactions, diversity and models/systems. By comprehending the conceptual base embedded in these themes, students get to appreciate the uniqueness of Earth in supporting various sub-systems.
- Understanding 2 is covered to some extent under the theme of interactions in the sections on abuses to life processes as well as in simple concepts of population community and ecosystems. The correlation between continued population growth and resource depletion is addressed in detail, and the necessity to moderate consumption in order to minimize the assault on the environment is underscored. A description in the syllabus demands, "Pupils should appreciate that a study of the interactions between and within systems helps man to gain better control of his environment". Also, in the theme of energy, the finite nature of fossil fuel resources is reiterated in the context of the need for conservation efforts.
- Understanding 3 is covered in significant depth under the topic of Science as an Inquiry. It also resonates well in other sections since the express purpose is to integrate it into the teaching of content in the various themes. Moreover, the emphasis on science process skills and thinking skills as well as on inquiry processes such as observation, problem-solving, logical thinking and decision making as a way to make sense of the natural world, as propositioned in the syllabus for the various topics, are in sync with GSL initiatives. Also, specific learning outcomes - for example, developing an awareness of the limitations of science and technology in solving societal problems, and developing sensitivity to the benefits and abuses of the applications of science, are consistent with a number of postulates of Understanding 3.
- Understanding 4 is covered in good depth under the section on Interactions, for example, topics such as chemical changes, forces, effects of heat, transmission of heat, etc demonstrate transformations that drive sub-systems. Also, the presence of life affecting the characteristics of other systems, is explored in energy transfer processes though the food chain as well as in the emphasis on conserving the physical environment as a means of protecting the ecosystem.
- Understanding 5 resonates in the section on cycles to a significant extent. Pupils are encouraged to note that the various cycles represent patterns of

change in nature, and that a study of these cycles helps man to understand Earth as a self-sustaining system. For example, the fact that materials making up the planet have been recycled several times is emphasized in the carbon and nitrogen cycles as well as in the recycling of nutrients trapped in living organisms and the role of decomposers in these processes. The topics of evolution and fossils are, however, not covered.

- Understanding 6 is not covered specifically as in the attributes of ESE but aspects of it resonate in other themes – for example, in the theme on diversity, the concept of elements constituting the building blocks of matter as well as constituting the materials in the universe is stressed. In the theme on models and systems, the emphasis that all matter in the universe is constituted of the three fundamental particles is reiterated.
- Understanding 7 – in relation to the study of the Earth using sample and data collection in the field plus analyses in the laboratory, is covered to a small extent in the section on measurements. The need for man to quantify his interactions with nature is stressed here through various means – for example, through the use of microscopes, electronic balances, and other measuring instrumentation for the extraction of data.

It is thus clear that the curricula in lower secondary science, whilst not grouped under the themes of ESS, do contain aspects of each of the seven postulates of ESS to varying extents and they cluster around the fundamental tenets of GSL. We estimate the weighting in relation to the convergence of the syllabus with respect to the various attributes of the seven understandings to be about 50 %, still a significant figure in the context of the current debate on global science literacy; the basis for this figure follows the approach outlined earlier for geography. More importantly, the pronounced emphasis placed on using examples related to the natural environment, devoid of any reduction interpretations and without a technological dimension, is a factor in promoting a worldview synonymous with GSL philosophy. The themes treat science as a continuum without any demarcations according to disciplinary focus, and also emphasize the humanistic dimension impinging on the various processes.

5. ELEMENTS OF ESE IN PHYSICS, CHEMISTRY, BIOLOGY AND GEOGRAPHY AT UPPER SECONDARY LEVEL

At upper secondary level, there is the segmentation of science into the separate disciplines of physics, chemistry, and biology - a departure from the GSL philosophy, which stresses a conceptual schema for organizing content in an integrated manner.

In all the science subjects, the syllabus has been structured in such a manner that there is less emphasis on purely factual material and more emphasis on the understanding and applications of the concepts and principles. The adoption of this approach is dictated in part by the recognition that students need to develop

skills that will be of long-term value in an increasingly technological society. Geography, however, is taught as such. It has the following specific aims:

(a) to understand the characteristics and distribution of physical (natural) and human (cultural) phenomena

(b) to understand physical-human relationship

(c) to understand processes affecting physical and human environments

(d) to develop an understanding of the different communities and cultures throughout the world as well as an awareness of contrasting opportunities and constraints which people face in different environments.

Content is organized thematically within the framework of physical-human relationship and human organization as follows:

(a) Physical Geography

- Weather and climate
- Natural vegetation
- Plate tectonics and landforms resulting from tectonic processes
- Weathering
- Rivers
- Coasts

(b) Human Geography

- Population
- Settlements
- Agriculture
- Natural resource utilization and energy
- Industries: manufacturing and services
- Development of physical and human resources

The geography taught is an extension of the concepts covered at the lower secondary level but at a higher plane. A noteworthy development is the modest amount of science covered in the subject. The extent to which the subject conforms to the GSL philosophy is now addressed.

- Understanding 1 is not covered explicitly since it has been addressed in the lower secondary level
- The consequences of unfettered population growth leading to resource depletion and strain on the ecosystem, as covered in the section on population, reflects significantly aspects of Understanding 2.
- The nexus between scientific thinking/technology and our ability to understand earth and space is reflected generally on how agricultural systems, hi-tech farming, wetland cultivation and plantation agriculture form the bedrock of conventional agricultural management systems – broadly reflective of Understanding 3. It is further continued in the section on natural resource utilization, where the uses of renewable and non-renewable resources are addressed. Various sources of fuel for energy purposes are also covered here. In the section on industries, the use of technology, especially that relevant from the point of view of Singapore's industrialization, is added to impart a local perspective. At the same time, the environmental and other undesirable effects of technology are stressed.

- Some of the attributes of Understanding 4 are covered in detail in the sections on physical geography – for example, plate tectonics, landforms resulting from the forces operative in tectonic processes, weathering, erosion, role of the Sun as an external source of energy in driving the distribution of rainfall, humidity, pressure and winds, temperature, presence of natural vegetation affecting the characteristics of natural environments, etc.
- An attribute of Understanding 5 – that materials making up Earth have been recycled many times, is covered for the case of water in terms of the processes leading to rainfall, in the section on natural vegetation relating to nutrient recycling, and also in the section on natural resource utilization in relation to renewable resources. However, the topics of fossils and evolution are not covered.
- Building on some of the attributes of Understanding 6 in lower secondary level geography, more content is disbursed for the appreciation of seasons, climates, tidal changes and day/night cycles in the topics of weather and climate, and pressure and winds.
- Aspects of Understanding 7 are covered broadly in a number of areas, for example, resource location is covered in natural resource utilization, and earth study is addressed in the topics of weather and climate, where the use of instrumentation to conduct field tests and analyses is emphasized.

It can be seen that the aims and themes are essentially in consonance with the seven postulates of ESE even though they are not structured as such and not all content is developed within this framework. We estimate the weighting of the attributes of the respective understandings of ESE to be about 50 % in the syllabus - the basis for this figure follows the approach presented earlier for lower secondary level geography.

5. COMMENTARY ON ESE ELEMENTS IN SECONDARY SCHOOL CURRICULA IN SINGAPORE

From the foregoing analyses of the science and geography curricula in secondary schools in Singapore, the following are the points of interest that emerge in the context of the current debate on Global Science Literacy using the ESE approach:

- Absence of disciplinary approach in the subject of science at lower secondary level
- Adoption of integrated perspective in the fostering of concepts in lower secondary science
- Significant weighting of ESE elements in the subject of geography at both lower and upper secondary levels: estimated to be 70 % and 50 % respectively
- Significant weighting of ESE elements in science at lower secondary level: estimated to be 50 %
- Use of disciplinary approach in the teaching and learning of science at upper secondary level
- Use of geography to teach a significant amount of science at secondary level

Whilst each of the statements in the seven understandings has a number of postulates, they can also be considered as scaffoldings for the development of order, structure and format for the attainment of these understandings. The seven understandings can thus be also considered as end-goals, which allow for a multiplicity of approaches for their realization. In the subjects of science and geography, the seven understandings of ESE are broadly followed via some of the postulates of the respective understandings and, in the others, via different ways. If weightings of GSL philosophy are assessed broadly for science and geography with respect to the title statements in the respective understandings, they would thus be necessarily higher.

The two-pronged strategy in the teaching and learning of science at the secondary level – integrated approach at lower secondary science and discipline-oriented format at the upper secondary level, is clearly a reflection of the need to achieve general science literacy at the lower secondary level and a more specialist focus at the upper secondary level.

The fact that some science is taught in a non-science subject, geography, is significant. Though there is a certain amount of overlap of coverage in geography and science at lower secondary level, it is a welcome initiative. It further reinforces the notion that the hybridization of science and geography underscores the nexus that both share with the environment. Also, it under girds the influence of the scientific tradition in what is generally perceived to be a non-science subject.

It could be argued that a drawback of the discipline-oriented focus in the sciences at upper secondary level is that they introduce content as disparate strands, thus making inter-connectedness more difficult. This is more a reflection of traditional educational practices worldwide, no doubt predicated by the prevailing political, economic and ideological order, which aims to gear curricular content towards addressing vocation-related competencies of a generic nature, and is thus not unique only to Singapore. There is, however, recognition that such disciplinary approaches do have some inherent shortcomings that would need to be addressed in the face of the onslaught emanating from the blurring of the boundaries between the various scientific disciplines and the integrated basis in which various scientific processes can be better understood. In an effort to address this in some measure, encouragement for project work, which is compulsory at the secondary level, has been promoted to a significant extent on a cross-disciplinary basis as well as the exhortations given for the use of collaborative work structures. Also, there are hybridized subject offerings such as Human & Social Biology, Science (Physics/Chemistry), Science (Physics/Biology) and Science (Chemistry/Biology) available for students.

With the rise of the Internet, wholly Net-based project work has also been encouraged. This entails, among other things, collaborating with students in other countries on relevant topics – a reinforcement of one of the postulates of Understanding 7, which states that (student) scientists from may countries throughout the world co-operate and collaborate using oral, written and electronic means of communication.

It is thus clear that ESE elements are covered in reasonably good depth at the secondary level in Singapore.

6. POTENTIAL FOR INCORPORATION OF FURTHER ESE ELEMENTS IN FUTURE CURRICULAR REFORM IN SINGAPORE

Curricular content organized within the framework of ESE initiatives offers several advantages:

- it fosters a relational perspective in the study of science, thus greatly facilitating functional understanding of the content taught
- it reiterates the need for students, an impressionable group, to have cognizance of the fragile nature of the earth, thus encouraging them to do their bit for the ailing planet from an informed perspective
- it offers an integrated perspective for the study of science

From the foregoing discussion, it is clear that there is a significant level of ESE elements in the subjects of science and geography at lower secondary level in Singapore as compared to in the past. The prevalence of an integrated perspective in the presentation of several concepts does endow on the curricula legitimacy and influence significantly cognizant of GSL philosophy. This is an important consideration in shedding the ambivalence for discipline-oriented courses at lower secondary level. At upper secondary level, incorporation of ESE elements is significant for geography. These developments suggest that the ESE debate is worthy of further support.

In our opinion, the potential for incorporation of further elements of ESE in the secondary level is good for the following reasons:

- Educational reform in Singapore is an on-going process. As explained earlier, there is a conscious effort to ensure that content taught is relevant and current. Exemplary practices from around the world are regularly and closely monitored and, where appropriate, are incorporated into the local context, often with some fine-tuning.
- The current debate on promoting global science literacy using earth systems education methods is being followed with keen interest in Singapore. The country's educational system is poised to undergo further reform, as there is concern that the system is producing examination-smart students. Curricular content is likely to undergo further revamp in order to accelerate the promotion of skills related to problem-solving, creative thinking and independent learning. Several best practices in the European and American education systems are being followed closely to see how these could be better adapted to local needs. In the context of the foregoing, GSL initiatives would be among the candidates that would present good scope to infuse the requisite attributes among students because content is geared in relation to the environment around us, thus presenting opportunities for intellectual introspection - a fundamental prerequisite for attaining conceptual understanding of the subject matter.
- At the National Institute of Education, the only teacher-training institute in Singapore, the authors have recently started studying how problem-solving skills, creative thinking skills and independent learning – pronounced emphasis now in the education system in Singapore, can be promoted through the use of

GSL tenets. Though the research is still in its formative stage, it is not out of place to state our general impressions on this:

(a) The nature of problem solving is that it is often a multi-disciplinary endeavor. An integrated understanding permits a clearer articulation of the problem and thus presents a broad view to synthesize solutions.

(b) Creative thinking is often a complex exercise. Whilst disciplinary subjects permit creative thinking for content in their respective areas, concepts taught in an integrated manner permit a holistic perspective to be attained, and this would be a factor in expanding the bounds of the traditional cognitive processes in students.

(c) Independent learning is facilitated in the context of the natural environment around us. By learning content that resonates in the world around us, opportunities are presented for better appreciation, and therefore greater understanding.

The opportunities presented for engaging in reflective inquiry when the natural environment is the experimental medium, as distinct from the laboratory setting for the investigation of many phenomena in the reduction mode, is a factor that cannot be overlooked in the fostering of the requisite attributes. Also, the cross-disciplinary connections that are spawned in such environments promote curiosity about nature, an important attribute in science inquiry. More scope is thus afforded for students to unravel the mysteries of nature, in the process also triggering concern for nature.

- The fragility of the earth dictates the need for an approach that expands the dimension of the problem among the younger generation. ESE initiatives factor in this thinking, as the basic construct of its philosophy is commendable. In fact, awareness of the environment has become more pronounced in Singapore in recent years (Tan and Subramaniam, 2001).

It ought to be reiterated that compared to curricula in earlier years, there has been a steady infusion of ESE elements in an integrated manner in the sciences and in geography in more recent years. Also, the teaching of science in a non-science subject, geography, in an integrated manner allows topics in the science/geography interface to be addressed from the context of ESE elements. This opens up another tributary for promoting Global Science Literacy. Overall, there is a significant but not complete convergence with GSL ideals, and the scaling-up potential is good.

7. CONCLUSION

Implementing Global Science Literacy by harnessing the curricular constructs of Earth Systems Education has a number of advantages -- it does not use the disciplinary approach, and content is organized holistically in a conceptual manner around the natural environment so as to foster greater understanding. Thus, it has the potential to foster science literacy at the international level in a pronounced manner bereft of any disciplinary limitations. If efforts are directed along reduction lines, an integrated perspective may be a challenge to attain as not all students get to study the respective disciplinary subjects in the school setting. Efforts directed along the

lines of the GSL philosophy would thus endow an educational system with the necessary ballast to help achieve at least basic science literacy in the widest possible perspective as well as reduce attrition rates among students in an overarching manner.

The foregoing discussion indicates that the curricular components in Geography at lower/upper secondary level and science at lower secondary level demonstrates a framework where there are several similarities between the content taught and the basic attributes of the GSL philosophy, even though content is not organized as such and the level of convergence is not complete. Obviously, by formatting content along the tenets of the GSL philosophy, there would be greater convergence. The significant weighting of ESE elements in science and geography at lower secondary level indicates that the GSL approach for organizing content presents a useful context for promoting science literacy.

Lower secondary science and geography are the stages that offer even further scope to foster an integrated curriculum pivoted around the seven understandings of ESE. It may not be that easy to implement this at the upper secondary level because of the disciplinary orientation and practical focus of the subject matter – a problem not unique to Singapore but also faced by other industrialized countries as well, no doubt underpinned by the utility of the sciences for a range of developmental needs in the economic, military and medical arenas.

The relentless pace at which globalization is formatting the politico-economic and socio-cultural landscape in today's society makes the vision of an integrated world a realizable dream. Concurrent with this development is the onslaught on the environment, which recognizes no boundaries. The need to promote a holistic view of global problems as well as maintain the sanctity of earth ecosystems calls for gallant initiatives in the educational systems of all countries so that the future custodians of our only abode - students, are infused with a broadband perspective of the stark realities facing the planet. GSL initiatives leveraging on earth systems elements can thus be prime candidates not only for the teaching and learning of science but also for the attainment of cognitive goals!

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CHAPTER 13: THE CHALLENGE OF GLOBAL SCIENCE LITERACY IN INITIAL EDUCATION OF PRIMARY SCHOOL TEACHERS IN PORTUGAL

Luis Marques, Isabel P. Martins, Nilza Costa, Lucília Santos, A. Soares de Andrade, University of Aveiro, PORTUGAL

1. INTRODUCTION

Teacher Education in the University of Aveiro (Portugal) is concerned with science in the curriculum of future Primary School Teachers. The experience is not only described but also interpreted in a theoretical framework.

The purpose of this chapter is to describe an experience that is being carried out in three sections:

- The first, related to the context in which science literacy is developed and also with their role in the science curriculum of Teacher Education;
- The second provides an overview about Teacher Education stressing its guidelines, difficulties and suggestions;
- The third, describes and comments on the conceptualisation, the design, the implementation of a new science subject in the curriculum of Primary School Teachers.

Limitations of the experience during the process are finally referred to.

2. SCIENCE LITERACY AND TEACHER EDUCATION

2.1.science education as a component of global education for citizenship

Social changes that are occurring all over the world since the end of the Twentieth Century have effects on life organization and also on the way information and knowledge are disseminated. The increasing rate of dissemination enables us to have a greater and more global awareness of what is happening across the world, in different societies with more or less contrasts. As far as basic educational needs are concerned these changes should be developed towards both a better management of the available resources and the search for solutions to international problems, such as: the overpopulation of the planet, the scarcity of food, the overexploitation of energy resources and of the sub-soil, the spreading of epidemics, the degradation of the environment, the drug traffic and so on. These problems require countries to act in a concerted way to maintain balance in the world (PNUD, 1999; 2000).

No doubt economic interests and political decisions play an important role for the solutions to these problems. Despite this, one cannot fail to take into account the scientific knowledge for an understanding of the respective causes and consequences. Nevertheless, science does not always elect the accurate solutions to these problems because scientific knowledge is rooted on finance dispensed by people and institutions that have not a healthy view of the natural world.

On the one hand scientific and technological development is neither linear nor independent from the dominant social and ethical values at a particular stage

and, on the other hand, a scientific view of the world is not unique. However, in order to solve a great number of questions, the importance of scientific knowledge cannot be ignored. Only science can provide a basis from which the effects of technology on the environment can be evaluated; only science can help to find solutions for the safety of the planet. Finally, only scientific methods will allow sound judgments to be made on questions that are international, national and part of people's daily lives (Rutherford and Ahlgren, 1990; Hodson, 1998).

This is the framework that guides, through a scientific-technological component, the personal and social education of individuals. Therefore, it is suggested that every individual should have sufficient scientific-technological knowledge for the understanding of the important phenomena in the world. In addition, democratic decisions will be taken in an informed way and with shared social responsibility. This position, although a widely defended and accepted principle today, raises problems about the means and extent to which it can be achieved.

Even though formal education represents only one part of each person's access to information and global education, this does not diminish the responsibility he/she has in contributing towards social demands. The question then is that of defining the boundaries of scientific knowledge proper for the school context, in such a way as to contribute towards the individual scientific culture and as a foundation for each person to build on the development of this knowledge.

2.2 Early science education in school

The need to promote basic scientific-technological education for all since the first years of school has been a common theme for the vast majority of researchers and educators in the light of the above. It is from this perspective that it is argued that primary school will always have to create some understanding, even if simplified, of the process and nature of science, as well as the development of a scientific attitude towards problems (Harlen, 1992). One of the functions attributed to this school level is to promote useful learning that makes sense to the pupils, as opposed to the simple acquisition of facts that is still defended by some.

It is in this framework that, in recent years, the teaching of science has assumed an important position in discussions about school curricula and the educational reforms of the early years of schooling, primary and elementary education.

Science teaching has ceased to be concerned only with the education of an elite of specialists, and is now considered an essential component of the basic educational foundation of all citizens. "Science education for all" has become the slogan in recent decades and this area has been considered fundamental for the understanding of the world that surrounds us. Several writers have suggested it should be viewed as an education for scientific literacy and not as the training of future scientists. Sciences are a part of basic knowledge that all individuals should have in order to grow and live in developed societies today. At the same time, they are the source of a greater equality and a better social integration that our children should not be deprived of (Charpak, 1996).

Moreover, a better development of science teaching at elementary levels may even constitute an opportunity for the much-desired educational change at these age levels.

Interest in questions linked to teaching and learning in these matters is clear from the vast amount of research and literature which has grown up in this domain over recent years, as well as the large number of projects in curricular research, development and evaluation which have been carried out in several countries, as well as in international contexts (see, for example, NTCM, 1991; Osborne & Simon 1996; CIEP, 1997).

However certain dissatisfaction also seems common in relation to the results and effectiveness of the efforts made over recent years to improve the scientific education of the younger sectors of the population. In fact, research seems to show that in spite of all efforts and the significant presence of science in the curricula of almost all countries, sciences continue to lack, particularly in pre-school and primary education, a status equivalent to that of other areas of knowledge, for example, language and mathematics (Osborne and Simon, 1996; Charpak, 1996).

In spite of the growing awareness of this situation - accompanied by a recognition that we live in a society strongly marked by science and technology for which it is necessary to prepare the children and youngsters who live and will live in it for many years - it is a fact that the great majority of teachers are unprepared and insecure to face the new challenges (CIEP, 1997; 38). This has been confirmed by several studies. Cole and Collaborators (in Sprinthall and Sprinthall, 1993), for example, conclude, from a study on interaction in science classrooms, that 95% of the time, more than 90% of science teachers use texts and not direct experiments; oral explanations, short question-and-answer exercises and work sheets dominate. Problem solving in laboratories continues to be reduced to a minimum. Osborne and Simon (1996) also refer to several international studies in which a reduced adoption and dissemination of science teaching in primary education has been revealed. Besides the lack of material and equipment in schools, the recognition on the part of those responsible (school administrators and principals) of the importance of these school curricula is limited, and teacher preparation is inadequate. Other researchers have shown that the absence of science teaching in elementary levels is due, essentially, to the feelings of insecurity, anxiety and uneasiness which many teachers feel towards sciences, highlighting the need to develop positive attitudes towards this curricular area and give more confidence to teachers as indispensable conditions for the expansion and the development of science teaching in primary schools (Osborne and Simon, 1996; Charpak, 1996).

Insecurity, anxiety, lack of teacher's preparation, these are good reasons for understanding what is happening with fieldwork in our schools. This has to be emphasized, particularly because fieldwork activities, if designed properly, should be an attempt to provide a holistic view in natural sciences. Therefore learning about the natural world cannot be carried out without observation, interpretation, hypothesizing and explanation of facts and phenomena taking place at the natural environment. Fieldwork learning activities are recognized by their particular features and specific methodology. The methanol that should be used during the trips includes many groups and sub-groups discussions, the raising of questions, both by

the learner and the teachers, the making of observations, the collecting and recording of data and the testing of hypothesis. All this should be taken into account in teacher's education in order to help them to feel much more confidant when they are faced with natural science teaching, even at primary level.

The determining importance of the teacher in the mediation of the curriculum and the impossibility of separating his/her thinking from his/her actions is recognized today (Shavelson & Stern, 1983). It is understood that, just as pupils have preconceptions which play an essential role in the learning process, and which must be taken into account when the teaching is being planned, so are teachers the bearers of a set of concepts, beliefs, habits and attitudes which influence their practice and which should therefore be taken into consideration when their teacher education is planned, be it initial or in-service (Furió Mas, 1994; Gil Pérez, 1994).

The way in which teachers interpret the curriculum and its alterations in times of change – which is strongly dependent on their personal theories about school, teaching, knowledge and learning and on their scientific knowledge – come to determine the teaching put into practice.

3. TEACHER'S EDUCATION AND PRIMARY SCIENCE CURRICULUM

Our students - future primary school teachers - will be teaching in the twenty first century and it is true that what teachers do depends on what is happening in the wider community. What teachers teach reflects the times in which they live. Therefore change is essential in education. In a rudimentary analysis, the teacher's job is first and foremost to ensure that the pupils learn. Nevertheless if this view covers a certain professional function, there are hidden perceptions of other not less relevant dimensions. Let us see that education is not only concerned with equipping pupils with knowledge and skill they need. It must help our youngsters to use leisure time creatively, have respect for other people, other cultures and other beliefs, become good citizens, think things out for themselves, and pursue a healthy life style (Dearing, 1994).

From the above, teacher's profile should be seen as corresponding to a person with a global perspective rather than someone only designing and carrying out activities in the classroom. Teacher education is therefore a topic of particular and in-depth reflex ion as an attempt to provide professionals of quality and able to play an important role, even in the definition of educational policies for the future. Documents recently published (CRUP, 2000)) have emphasized the indubitable relevance of rethinking Teacher Education in Portuguese Universities. The definition of main areas of competence and capacities for the teachers in general and science teachers in particular, is already been put forward (Araújo e Sá and Costa, 2000). In a holistic and interactive perspective of teacher's competences the following areas have been defined:

. Cultural, social and personal education related to the development of reflexion capacity, autonomy, cooperation, participation and open mind to different forms of contemporary culture;

. Scientific education concerned with the contents that should be taught;

. Pedagogical education dealing with self-reflection about educational problems of our present society;

. Development of teaching competences that should be integrated in the teaching practices in order to become able of developing accurate solutions for solving practical issues;

. Development of critical analysis capacities and attitudes, of innovation and pedagogical investigation towards the production of new knowledge and challenge of situations.

Let us go further and think specifically about primary school teachers and on their scientific education, particularly at University of Aveiro. At this school it was argued that, as far as science is concerned, the following four components should be considered:

. The nature and the meaning of science and their social and cultural context;

. The learning of science (global subjects rather than specific subjects);

. The learning of how to learn science;

. The learning of how to teach science at primary level.

The first dimension is an important one even at the primary level. The image that many pupils have of science and how it works is often distorted. The myths that our learners have about science are not dispelled when science teaching focuses narrowly on concepts and laws. To realize that it is necessary to overcome this view seems to be important.

The second dimension is particularly relevant when one talks about primary science curriculum, as it will be discussed further. What one bears in mind is to help pupils to start to understand broad concepts towards being familiar with the natural world.

No doubt, the third dimension is a difficult one in Teacher Education. There is no course at initial education that can teach enough science in order to get teachers well prepared for the future. Therefore, they must be motivated to involve themselves in future learning activities, as well as to interact with other teachers in schools.

Research studies (Frost, 1997) reveal, about the latter dimension, that the main purpose is to learn science as a whole and continuous process in a social context. To achieve this issue children must know:

. Things about the natural and made world;

. To understand explanations of how things happen;

. To be familiar with some scientific concepts;

. To ask questions about what causes things to happen and how people achieve in producing such explanations;

. To understand experiments, deciding about the procedures to find evidence for answering questions;

. To achieve an enjoyable relationship with the environment through field work activities;

. To feel that fieldwork activities are as relevant as classroom or laboratory practices as far as science teaching is concerned;

. To formulate hypotheses about the results; interpret data, understanding how data was collected;

. To classify, compare, observe, measure, record, describe, and manipulate objects and apparatus;

. To communicate ideas.

A final comment, in this section, about science in primary school curriculum (6-10 years old): *The Study of the Environment* is an area in which one can find Social Sciences, History and Geography. Moreover, the national curriculum does not stipulate exactly how science lessons should be conducted. Therefore, what in fact happens in the classroom is strongly related to the level of teacher knowledge about the subject and also to their skills concerned with science teaching.

Practical work plays a crucial role in science teaching, even at the level that we are talking about. In Portugal, nowadays, it does not make sense to comment on this important issue, i.e. practical work in schools, without giving a note about the Project *Ciência Viva* launched in 1996. This is a Project sponsored by the Ministry of Science and Technology rather than the Ministry of Education. Its main aim is to promote both scientific and technological culture in Portuguese society - a central concern of the national science and technology policies – and to create a greater understanding of science education in schools. Strategies carried out make an attempt at promoting the teaching of science through experimental activities assuming that they are fundamental to a lively learning of science.

The relevance of this Project for the amelioration of the equipment in the primary schools that are involved is great. At this stage schools can apply to the Project Ciência Viva through the design of a thorough plan of activities. Nevertheless this means that the teachers have to be well prepared in science and science teaching, something that must be also developed through in service training.

With this reference in mind, the teaching of science in the first school years must be based on pupil's experimental work, organized in a cognitive conceptual framework, in which pupil's ideas are a very important starting point.

4. GLOBAL SCIENCE IN THE CURRICULUM OF PRIMARY SCHOOL TEACHERS

4.1. An Overview Of Science Curriculum Before Global Science

The aim of this section is to provide the reader with a perspective of science in the curriculum of students, future Primary School Teachers, in the foregoing period of ten years, before the designing and implementation of the subject Global Science. This curriculum was developed through a three years Course.

As a starting point, it should be emphasized that the idea of introducing science in this curriculum offered no discussion at all even at that time. The responsibles for the curriculum joined the campaign to make science teaching a part of the school curriculum mainly to improve the general welfare of society through education.

Nevertheless, science contents, during this previous period, were organised in the assumption that the students would gain a coherent and organised knowledge

of scientific principles through an understanding of the principles of each separate science field.

Therefore, a subject labelled Levelling Course in Science I (there was another one related to Maths) integrating four separately modules - Biology, Chemistry, Geology and Physics - was designed.

The modules, as a whole, took eight hours a week. They were conceptualised in a disciplinary point of view. An educator lecturer with a specific scientific background taught each module and, therefore, the contents were mainly related to a particular view of the area of knowledge, without appropriate links among them. In other words, the students were faced with a framework rooted on areas of knowledge rather than on a framework based on scientific themes. Practical activities, either in the laboratory or in the field, were also in accordance with the organization of the subject.

The lecturers, through the logic that each module worked like an individual unit, developed the approach in each module individually. The facts were taught as isolated information and it was supposed that it would be understood. As far as the assessment is concerned, it was also carried out in and individual way in each module.

Informal talks with the students reveal that most of them claim for unifying themes to organise the contents and, therefore, the approach that has been developed needed to be rethought. In addition the students complained about the length of the subject taking into account that, from their point of view, they had to prepare four subjects rather than one.

From the picture drawn above and also from the context of science education nowadays, described in the previous sections of this chapter, it is easy to understand that the team responsible for science teacher education, particularly at primary level, has recognised that an in-depth analysis of the science curriculum to future primary school teachers was crucial.

Discussions towards the designing of a new four years Course for Elementary School Teachers took place at Aveiro University in 1997. This situation created a very positive context to develop the analysis of the science area in teacher education for the students enrolled in that Course.

4.2. Global Science: How It Was Developed

This section starts with a brief reference to the target audience of this subject. For the purpose of enrolling, students have to pass a test on Portuguese language. Learner's scientific background may be relatively different, i.e. there are a few who had science up to 12th level (secondary school) but, most of them, finished their learning of science at 9th level (compulsory school). Therefore, it is true to say that the majority of these students reveal weaknesses at the level of their scientific background. This is not a new or unexpected scenario, since it is well known that this situation is found in many countries (Charpak, 1996). It is an important point in our country because the primary school curriculum in Portugal is very demanding as far as science is concerned.

Considering both the previous experience described in outline and the theoretical context referred to at the beginning, the relevance of looking for an alternative to the way science is organized and implemented in the curriculum of primary school teachers is obvious.

The new subject emerged from two assumptions:

First of all, the designing of the syllabus should be carried out for helping students to achieve the development of attitudes, sensitivity and concerns for the improvement of the comprehension of the natural world.

Second, a holistic view of the relationship among facts and concepts towards the achievement of wider bodies of knowledge rather than a restrict view based on a long list of curricular items as a merely accumulative vision and a view of science out of context, is crucial.

These assumptions have been considered from the very beginning of the process, when the team responsible for the conceptualisation of the programme was organised. It was not an easy task to join together scientists from five different areas, particularly when teacher education and teaching are the issues under discussion. In fact, as far as teaching is concerned each scientific domain is usually confined to its own area with weak interactions with other areas (Costa et al., 2000). The existent links are developed at the level of management of curricular contents, rather than at the level of the conceptualisation and designing of the relationship between curricular concepts and also their corresponding approach.

Something different has occurred throughout this experience in relation to the team responsible for the designing and articulation of the contents of the Global Science. It was decided to get into the group, on the one hand, scientists and educators with a broad scientific background from biology and chemistry to geology and physics and, on the other hand, elements with a common view about laudable aims which help students to achieve a responsible citizenship through science education (Watts and McGrath, 1998; Hurd, 1998). The constitution of the team was as follows: four educators specialized in biology methods, chemistry methods, geology methods and physics methods, respectively, a biologist, a chemist, a geologist and a physicist. It should be stressed that the latter three were very keen on science education. The good personal relationships between the different elements of the group are an aspect, which should be stressed. This point and also a set of common concerns related to both teacher education and the relevance of science in Primary School teaching explains the availability of the lecturers for participating in this challenge, despite the amount of tasks they already were responsible for.

The main aim at the starting meetings was to reach a common denominator concerned both with the core concepts which should be taught and, particularly, with their relationship towards the achievement of a holistic view of the world. This was a demanding and very powerful exercise for each of the group participants, taking into account that nobody had already took part in a similar experience. Nevertheless, if on the one hand it was a fussy task, on the other hand, it was a very rich one from a personal and professional point of view.

Three main topics i.e. Sun, Earth and Life, emerged from the discussions that took place, as having a very high level of relevance and also a potential (for themselves and for the relations they establish between each other) to give a

contribution for the understanding of the way our Planet works, as system of sub-systems (Mayer 1998).

Life, in a very broad sense, can be seen as the starting and final point of Science Education. Comprehension of the context and sustainability of Life on Earth and also the role played by the Sun, as a very particular source of energy seems to be crucial. Nevertheless, detailed information about the relationships put forward, is revealed in the diagram of Figure 1.

In fact solar radiation is, from a human scale, essentially undepletable and is also the most abundant source on Earth. This latter is a unique place, a dynamic system which is powered partly by the planets own internal energy but mostly by energy from the Sun around which it revolves (Merritts et al 1998). It should be emphasised that Earth's internal and environmental systems are strongly rooted in the way the Planet evolved within our Solar System.

The context referred to, before, in outline, was an accurate one for the development of Life. If it is not easy to provide a precise definition of Life: living organisms reveal some attributes, such as self-replication and capacity for self-regulation. A very complex framework responsible for the origin, development and maintenance of Life reveals that a very strong interaction of different factors was vital in the past, is still vital nowadays and will be vital in the future. Biodiversity is presented to the students as a relevant aspect of Life, based on the different organisation of the structural unit of living beings, which is the cell.

4.3 Functions of and approaches to science concepts in global science

There can be no doubt about the importance of an accurate definition of the aims for the designing of any subject, and even for the approach selected. In other words, the aims contribute for the definition of the framework in which the implementation of the syllabus takes place. The following aims have been defined for the subject under discussion:

. To understand natural world phenomena, on the basis of principles emerging from different areas of scientific knowledge;

. To recognize both that the planet Earth is a well structured set of sub-systems in an in-depth and balanced interaction and that human beings are responsible for keeping this balance;

. To understand scientific issues in their historical, social and cultural context;

. To develop abilities and attitudes which enable an enjoyable science teaching and learning.

. Two different types of classes have been carried out - theoretical lectures and practical classes. The formers, are lecturer centred, despite the fact that students are frequently invited to participate by raising questions or putting forward their doubts. The themes are mainly presented in strong relationship with social and environmental issues. This is an attempt to help students to achieve a positive attitude about, for example, problem solving through the analysis of items that are geared to the subject area concerned, where there is a huge range of possible questions to be solved. The history and nature of science are also dimensions

stressed during these lectures. It is assumed that once people gain a good sense of how science operates - along with a basic inventory of key science concepts as a basis for learning more later on - they can follow the science adventure story as it plays out during lifetimes (AAAS 1993).

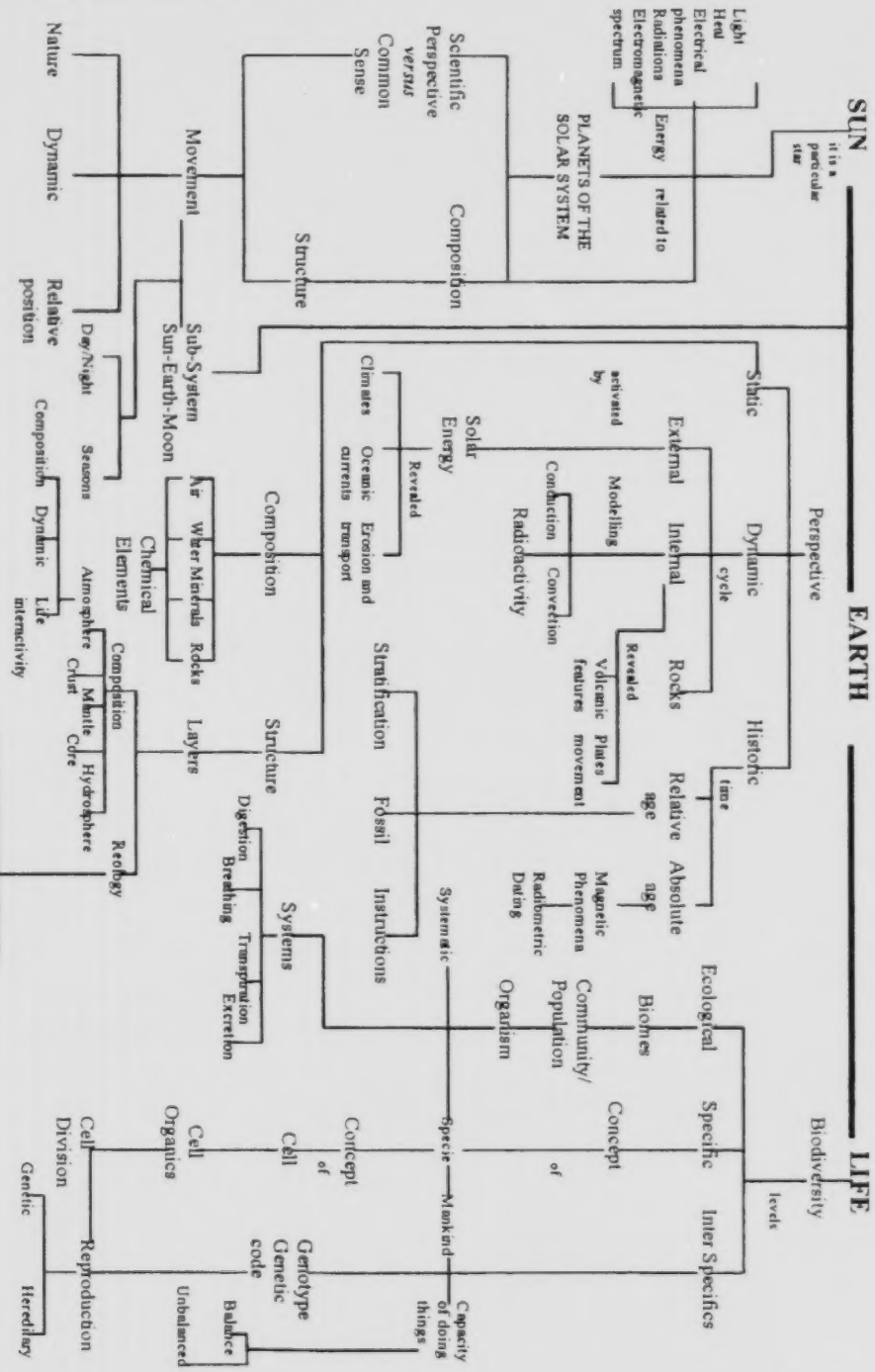

Fig. 1 - The figure represents a Conceptual Map showing the relationship among the different concept of the syllabus.

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The approach of the different topics of the syllabus would be a very demanding task for only one lecturer and, therefore, it was decided to indicate a group of four, each one with a specific scientific background, for doing it. The group discussions have still continued after classes started and this enables us to decide, on time, which will be the person responsible for lecturing this or that class. Theoretical lectures take three hours a week.

There are no doubts that practical work is now widely accepted as an integral part of science education. Solomon (1980) has stressed this perspective by writing in relation to the role of the school laboratory as follows: "science belongs there as naturally as cooking belongs in a kitchen and gardening in a garden".

A set of assumptions presented below underlined the practical activities that have been designed:

. To maintain interest, satisfaction, open mind and curiosity;

. To define accurate methodologies for finding solutions for the problems;

. To help the development of skills of interpretation of data collected;

. To stimulate skills on communication.

Practical classes with 16-18 students, taking two hours a week, were carried out in the laboratory and an attempt was done to fit the nature of these activities with the topics that are presented at the theoretical classes. The students are organised in groups of four elements.

All the tasks started from a particular problem mainly presented by the teacher but, sometimes, put forward by the students. Nevertheless, it should be stressed here the three main phases occurring during practical work.

There was a first phase for the students to become aware of the problem. This means that they had to reflect on:

. The nature of the problem that they are faced with;

. The recognition of its relevance in terms of a way of interpreting the world, rather than a matter of how much is learnt.

A second phase is concerned with the planning of a procedure to investigate the problem. This is carried out in different ways with more or less interaction between students and teachers or among students. Nevertheless all of them are attempts to reach, on the one hand, the learning skills and science concepts, and, on the other hand, the learning of higher cognitive level aspects. Class discussion, group discussion and, sometimes, guided procedures are the strategies which have been used to look for the best methodology to find solutions for the problem.

A third phase is about the implementation of the plan that is close to the designing carried out before. The students, working in groups, carry out the preparation and making of the experiment itself and collect the data for subsequent analysis and interpretation. As far as rigorousness is concerned, the lecturer follows what is going on in the groups, making a careful supervision of the several procedures, helping students to recognise the relevance of being careful and being conscious that they are doing an exact task.

Interpretation of the data obtained from practical activities was carried out in work group. More or less in depth discussions took place among the students or with the lecturer. A particular attention is devoted to the analysis of cases related to

the achievement of different results related to the same experiment. Attempts to look for explanations for these issues are developed.

At the end of the experimental activity, a small report was written by each group and provided to the lecturer for comments and analysis.

As stated before, the practical work, that we call experimental activities, was carried out in a laboratorial environment. We also think that field activities would be of great value in this cooperative learning process, if it is assumed that they are based on facts or events from our every day life. For example, when contents such as Sun/radiation/light (see Fig.1) are taught, the students come out of school and go to town looking for objects or aspects that can be linked with these topics. At the corner of a more or less busy street there is a convex mirror. Each group should raise questions, for instance, "why not a plane mirror?". From this elementary methodologies are designed to reach an answer.

Also, under this topic for field work, Global Science emerges - since they are dealing with light and sight, optical instruments are in order: to observe small living beings, to analyse some fossils in a rocky environment or to explain why they see a rainbow when it rains.

In a Global Science approach it is a challenge to look for field activities that can help students to understand better the strong link between natural events and our every day life. If it is true that observation is theory leaded, it is important to learn to observe and to collect data properly. Scientific knowledge doesn't star with observation, but doesn't exist with the lack of it.

In our curriculum of Primary School Teachers all these perspectives are taken into account and, therefore, laboratory and field activities are really environmental learning at different stages.

Let us see, for example, at least in outline, the nature and the context of the different laboratory activities with which the students were faced.

A. Three activities were designed related to one of the three main topics - the Sun -:

. . Composition and features of the light coming out from the Sun; its behaviour on different types of surfaces;

. Types of mirrors and characteristics of the images they provide. Concave or convex mirrors are used in particular situations in our everyday life - looking for explanations;

. Dynamics of Earth and of other planets of the Solar System; interpretation of the different speed of the planets closer to the Sun and of the others. The starting problem was the succession of day and night and of the four seasons throughout the year.

B. The following activities were planned concerned with the other main topic, i.e. the Earth:

. Structure, composition and relevance of the atmosphere. The role played by the effects of acid rains that are a real problem of our society nowadays;

. Water as a crucial resource for the next century. Methods that are used in order to maintain water in appropriate conditions for mankind. Designing of a methodology for getting potable water.

. Rocks and minerals on the surface of the Earth; its origin and composition. Raw materials and its relevance. Analysis of cases revealing that industries, energy production, chemical processing, manufacture of building materials all depend on a steady supply of reasonably priced minerals, rocks and fuels. Social, political and environmental aspects are also involved.

C. One can stress the activities referred to below dealing with the last topic - Life:

. Life as a complex process at balance with natural issues. Preparation of an appropriate weekly diet for a school refectory; discussions take place related to a set of aspects which should be considered e.g. the age of the students, food properties.

. Labels concerned with different kinds of food and drinks provide an important amount of information. Different types of questions related both to the meaning and the students and the lecturer raise consequences of this data. Appropriate ways for solving these aspects are designed and discussed.

5. STUDENT'S VIEWS

The assessment concerning student's attitudes in relation to the experience that they were faced with was carried out through the administration of a questionnaire at the end of each academic year course i.e. 1999 and 2000. Through the analysis carried out so far, the following aspects can be already put forward:

. On the number of lectures attended - less than 25% of the students miss the lectures. But the number of students attending more than 50% of the lectures increased from 1999 to 2000;

. On the logic of the theoretical lectures - more than 50% recognize both the logic of the sequence of the topics that are being presented in the theoretical classes, and also their clearness. A quite small percentage, less than 10%, reveals an opposite view.

. On the purpose of the theoretical classes - more than 60% express the opinion that they understand reasonably well their objectives, although 25% of the remaining students state that they fully understand the objectives of the same lectures. Less than 5% couldn't see the evidence both of the objectives and the topics of the subject;

. On the articulation between the theoretical and practical classes, 80% of the students find that it is high. Less than 10% argue that the topics presented in the lectures are not related to the activities carried out in the laboratory;

. On the contents approached in the theoretical lectures, a large majority of the students, more than 80%, claim that they correspond mainly to topics which interest themselves and gave a contribution for a better understanding of the natural world. Less than 5% argue that the contents proposed do not provide relevant knowledge to explain the phenomena of the natural world and are not enjoyable.

. On the shortcomings of the subject; 30% of the students dislike the high number of lecturers involved;

. On the effectiveness of the bibliography provided, 50% of the respondents revealed satisfaction;

. On the level of complexity of the topics taught, 20% have the opinion that they do not offer difficulties. The remainder reveals an opposite view;

. On the scientific background, 35% of the students stress that they have a notorious lack of previous scientific knowledge concerned with the issues presented on the syllabus.

From this set of results, it seems clear that the overview of most students about the curricular contents and the structure of this new subject are mainly positive. The lecturers are analyzing the difficulties felt by the learners; attempts to help students to overcome those difficulties are made at this stage.

6. FINAL COMMENTS

All the authors of the chapter have integrated the team responsible for the conceptualisation, designing and implementation of this syllabus. Therefore, in a certain way, this document reveals their view concerning their perspective about the nature, the development and the potential of the subject under discussion.

Meetings with the lecturer's participant still occur for the discussion of a set of aspects that have to be improved, such as evaluation and bibliography available for the students. The team responsible is making an attempt to organise instruments for student's evaluation (for example, tests) that should be a mirror of the global view of science presented through the syllabus.

Appropriate bibliography for the students, reflecting the perspective that underpins the subject Global Science, is an important aspect not completely solved yet. The writing of appropriate curricula materials is a project that is starting to be analysed and discussed in more detail.

At the end, the authors feel that the acceptance of this challenge was a factor of great personal satisfaction, and an experience that is providing a new perspective in both scientific and educational areas. So, we would like to emphasize the importance of developing a broad and varied discussion with all colleagues from other institutions who are interested in this issue and have already been faced with similar enrichment experiences.

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CHAPTER 14: GLOBAL SCIENCE LITERACY: FROM GEOLOGY TEACHING TO EARTH SYSTEM SCIENCE TEACHING

Pedro W. Gonçalves, and Celso D. R. Carneiro, The State University of Campinas, BRAZIL

1. INTRODUCTION

Some experience on teaching at the undergraduate level allows us to investigate the essential topics and the skills of the Earth sciences education that would help to prepare geologically conscious citizens. The skills and topics, to be included at the college education level, comprise what may be called geoscientific literacy – the earth sciences component of Global Science Literacy (GSL). The studies on the Earth started from a disciplinary approach into a broader scope that progressively included the fluid terrestrial spheres, the integrated knowledge on the Earth history, the biosphere and the environmental problems. This historical perspective on the evolution of the studies of the Earth is a basis to enlarge the horizon of future geography, geology, and science teachers. At the end, it should reveal competence that has been currently required from any citizen – the ability to understand, to analyze and to take a position in respect to the scientific and technological problems affecting the terrestrial environment.

Continuous research on teaching at the undergraduate level has allowed us to produce this Chapter. The students we have dealt with during the last 15 years vary greatly in their knowledge and areas of scientific training. As long as their career paths are diversified, all of them expect to get some training on natural and experimental sciences. They study engineering, geology, geography, biology, chemistry, etc. Many of them will be teachers at the elementary and high school education levels. This experience prompted a few questions: a) what is essential to science education? b) What is the most important aspect of the Earth science education in the making of a conscious citizen? c) How this can be done? d) What are the skills and topics that should be included at the basic education level?

This is the context for a research project on basic elements necessary to understand natural sciences and how we can teach them to graduate conscious people. The questions guided us to define some required topics, contents and scientific knowledge for the education of future citizens. The contributions of the Earth Sciences to Global Science Literacy (GSL), seen as ***geoscientific literacy***; comprise the analysis of the evolution of Earth Sciences teaching elsewhere as factors that can stimulate a broadening of horizons for the future geography, geology and science teachers.

It is also our objective to outline the historical development of the Earth studies from a disciplinary approach mainly concerned with mineral and energy supplies to a progressively broader scope that includes studies on atmosphere, hydrosphere and space. During the 1980's the integrated studies of the Earth included the study of the biosphere and the environmental problems. This evolution of the knowledge on the Earth is the basis for a competent citizenry that

is able to understand, to analyze and to take a position in respect to the scientific and technological problems regarding the terrestrial environment.

2. A STARTING POINT

It is broadly recognized that geology topics are poorly developed at the elementary and high school levels in Latin America (from 7 to 18 years old). Some countries – Brazil is included among them – do not allow an autonomous development of the Earth studies, mainly between 7 to 11 years. For the major part of the students such themes – when presented – are in programs of geography or natural and experimental sciences. After this phase, between 12 to 15 years old the students are addressed just to a few hours per week of classes on biology, physics and chemistry. This requires a minimum of knowledge on geosciences by the teacher and little motivation to acquire more.

Geology offers the possibility to get a global and integrated way to understand all the processes of the planet. First, it teaches people living on active regions of the Earth's crust, as the Andean chain for instance, what actually occurs there. Second, for people living elsewhere, geology provides an understanding of remote natural forces and the opportunity to perceive Nature. Several authors emphasize this role of geological science as it contributes to a greater understanding of the interrelationship of social and natural processes (global climatic changes, natural hazards, etc). They also contribute to the natural dynamics in the scale of deep time (the global dimensions of the Earth's time and space), to the importance of certain discoveries and to concepts of cultural perspectives (discovery of geologic time and characteristics of natural cycles). This branch of knowledge changes the way people think and perceive the world. This change is paramount to the understanding of the environment. However, there is a strong obstacle – the social image of geology and the geologist.

Despite all these factors, general geology is associated with the classification of rocks and minerals; the theory of plate tectonics; and mining of energy or metal resources. This is a very limited view of geology: our students, at the introductory geology course, do reveal it. They aspire to study geology, geography or biology, however they start with a low level of scientific knowledge.

2.1. Evolution of a discipline

Introductory geology gives a person the basis of a very diversified field of knowledge concerning the planet, as well as the skills needed to process different kinds of information on this issue. A fundamental step to reach an understanding of the basic concepts of geological history is to understand how geology evolved to a broader approach of Earth Systems Science teaching.

This Chapter presents a brief history of geological science as it refers to a few decisive moments as long as they are important to understand the current dynamics of our planet.

2.2. *Evaluation steps*

At the undergraduate teaching level, a certain kind of "top" of the educational pyramid, our students are evaluated before attending the introductory geology courses. The evaluation process also confirms the importance of an introductory Earth system science discipline (Carneiro et al. 1998, 2000). The results of this preliminary evaluation are disheartening – they often show a low knowledge of geological themes. In general, there is little interest on geology because they live on a stable cratonic Precambrian shield that is not affected by earthquakes, volcanoes, tsunamis, etc. They deem to be enough to have a sketchy picture of the evolution of species from biology and rudimentary concepts of plate tectonics from geology. The simple evidence of extinct fauna and flora may be ignored as long as they have such poorly developed concepts. This is a result of a vicious cycle – their former teachers had low knowledge of geological themes and were not motivated to heighten them. The consequence is a poor teaching quality that can go on and on until one is suitably qualified to teach geology. To interrupt this cycle and improve the quality of geology teaching require investment directed towards the teachers.

The students in general do not have basic knowledge of system processes and they are not able to see the relations among processes of systems like the air or water cycles – relations among water, erosion and sedimentary processes (not to mention the deep time scale).

Nevertheless, the knowledge of the planet Earth has undergone an astonishing fast progress, mainly during the last ten years. As the human population grows and newly available technological tools replace former ones, a sharper understanding of the planet has been constructed. However, a person who does not have any familiarity with science topics and scientific reasoning is severely limited in understanding the changes occurring around him. Teachers having a low knowledge of Earth Sciences are not able to keep abreast of the continuous flow of data and information on the scientific discoveries regarding natural sciences – climate, weather, natural hazards, evolution of species and so on.

In spite of this typical educational "disaster", we advocate that the environmental overview provided by geology is linked to time and space scales and to the geological records.

3. CHALLENGES FOR SCIENTIFIC LITERACY

The educational system is the formal way to acquire a background on science and scientific concepts. We follow the guideline necessary to lead young people to the understanding of the nature of science and to the links among science, technology and society. To understand the nature of science is necessary to develop specific notions, concepts and theoretical structures. In order to make these clear we use classical contributions, philosophical and historical analysis of science, starting

from a number of available approaches to demonstrate how science works – from the classical studies of empiricism to sociological approaches. However, the nature of science is only clear when we are able to show that science is a human activity. As a result of human work, science is made by means of internal and complex rules of validation. At the same time, science is the result of cultural, economic and social needs to human progress, welfare, etc. In other words, science is a cultural activity linked to technological and social necessities. Thus, the current scientific activity is an essential part of our modern culture.

Teaching science contributes to the development of skills and values that reject indoctrination or conditioning – a citizen must be able to justify his beliefs. An important aspect of scientific literacy is the understanding of the ideas and concepts produced by the scientific community as well as the relationship of these concepts among themselves and along with general explanation and broader theories. These notions should be seen in the context of the culture that generated them and how they affect that same culture.

Knowledge of the fundamental Earth science topics may change one's view of the world and men. For example, the replacement of the geocentric model by the heliocentric model; the span of Earth age from few thousand years, admitted by biblical time data, to a time span up to some billions of years. Not to mention the idea of deep time which is a key geoscience concept to be included in science literacy education as regarded by Trend in Chapter Four.

4. HISTORY OF GEOLOGY

Geology, together with biology, is a branch of knowledge that stemmed from natural history. Its methodological structure and overall comparative studies were derived from natural history. Comparative work has been strongly supported by the idea that the genesis of the natural materials is known by means of their characteristics. This makes possible to distinguish and to classify materials. Nicholas Steno (1638-1686) systematicaly adopted these types of classification, associated with the genesis of natural objects in the modern era. However, these types of classification were only incorporated to science during the eighteenth century. At that time, they became the key to order, classify and determine the genesis of rocks, minerals and the organic origin of fossils.

The cultural implications of these studies of nature were enormous. They derived from the introduction of some concepts and progresses – the duration of the time of Nature (with the development of a geological scale); the standardization of observation and description of natural objects and processes; the beginning of generalization of field activities and geologic mapping; the early systematic pictorial and landscape representation; and the beginning of representations of the units among the rock types. The representation of the rock order in space, the standards for rock classification and generalization of field activities were procedures that arrived close to the studies on origin, genesis and processes of rock formation during the eighteenth century. These processes would be identified and mapped in accordance with their expression in space and time (Gonçalves, 1987).

The information collected and represented on maps were essential to the idea that the natural processes would be cyclical. There were ways to establish rational relations among phenomena with seemingly little connection—formation of soils, erosion, climate, uplift of continents and mountains, formation of rocks, etc. Moreover, these processes would have been repeated several times in the history of Nature. This coherent formulation was adopted by James Hutton's (1726-1797) dynamic view of the Earth.

The Steno's principles for classification and ordering each class of stone strata and for defining their origin got a special meaning in the second half of the eighteenth century. They helped to elaborate the classification of rocks and the first stratigraphic maps (Ellemberger, 1989; Rudwick, 1978).

The end of the eighteenth century is usually considered the birth of modern geology because of these important approaches and concepts to study minerals, rocks and the Earth. The growth and generalization of field activities, the bond between geology and mining, the spreading of the use of maps and other visual diagrams to study natural history are significant events of this new modern science. Moreover, there was a narrow connection between the mineralogical knowledge and chemistry, which is the basis for mineralogy as a science from what geology was originated.

James Hutton's ideas are particularly relevant to the development of geological science (Sequeiros, 1997). His writings revealed the differences between working with samples in a lab and testing ideas on fieldwork – hypothesis, explanation and theory – the historic method used by historical sciences, a process that is analogical, multifactorial, hypothetical and narrative. Hutton used actualism to develop his ideas (Gonçalves, 1997).

A central theme was the characterization of mechanisms to explain the uplift of mountains, continents and their association with erosion and sedimentation. In the middle of the nineteenth century, geosynclinal theory synthesized this rational and compatible explanation on natural data. It provided the advance of regional studies (a study of the continents) and a set of diversified theoretical and practical implications to discover mineral resources, mainly metallic ores. The geologic cycle has provided a basic and general mechanism for the study of the Earth that had implications to mining.

There were other advances with the twentieth century. The knowledge of the continents expanded, however many problems arose to which there were no satisfactory explanation at that time. Mainly after the Second World War, information on the internal structure of the Earth and on the oceans (topography of oceans, marginal sedimentary basins, and age of oceanic rocks) yielded doubts. At the same time, a new view of rocks, minerals and continents was emerging as a result of different geophysical methods applied by geologists.

The improvement of geophysical research methods was the central factor in the making of the plate tectonics theory. It has been also a major factor in its constant redefinition for the last thirty years. The theory has changed the interest

area of geology – from continents to oceans (the present and old seas). It made possible to relate several processes and the interaction of terrestrial spheres (core, mantle, crust, atmosphere, hydrosphere and noosphere). Regional geology was replaced by a global and integrated study of the Earth (Praia, 1996).

Moreover, applied studies on the Earth have been developed in the past fifty years branching from areas like engineering, hydrology and land occupation. These fields of study opened a way for environmental geology.

5. HISTORY OF EARTH SYSTEM SCIENCE TEACHING

We reconstructed some capital moments of geology teaching by means of a few reference textbooks. We noticed that there was a growth and enlargement of the geological focus in regard to the history of geology and the history of geology teaching. This is important for teaching geology because one can adopt a geological approach that helps to understand the natural processes of the surface of the planet in conjunction with social processes, a critical obstacle for production of educational materials for a global literacy on the Earth.

We believe that some perspectives influence the presentation of contents, topics and approaches of textbooks for introductory geology. For example, some books entitled *geology* or *physical geology* are centered on rocks and minerals. They are often divided in two parts – the internal and external dynamics of rocks and the crust. Arthur Holmes' *Principles of Physical Geology* (1979) is organized in this manner as well as many other books on introductory geology published in America and in Europe. In Brazil, the classical textbook *Geologia Geral* by Viktor Leinz and Sergio E. Amaral (1989) follows this same pattern. This frame of contents and approaches allow training students to understand economic geology of metallic mineral deposits. The titles delineate a fragmentary thematic structure. Sometimes, these books resemble an encyclopedia of geology. Some other books usually entitled *Geology* present the planet through the successive geological eras. Nevertheless, both groups of books emphasize the geological record. The view of geological science that is conveyed by these books is a classificatory branch of studies – this branch considers local and regional characteristics (singular facts) by means of examples. The applied field more quoted in these books is mining. The main subject matter is the geological record (rocks, minerals, structures); that can be accompanied by the description of processes and origin, instead of treating only the products of processes. In other words, these are books for teaching by transmission. In sum, knowledge should be learnt by transmission and repetition.

The movement for innovation of science teaching, important in the sixties and in the seventies, was marked by new curricula on different areas of natural and experimental sciences. The new curricula intended to wake up students to science (Matthews, 1994). Textbooks called *Geoscience* or *Earth Sciences* are dated from this time, as the *Investigating the Earth* (Earth Science Curriculum Project, ESCP). The thematic cover is remarkably broader than physical geology. The geoscience tendency within includes introductory geology, current processes of the atmosphere, the hydrosphere, the Solar System and the space science. Processes

acquire special treatment with the same emphasis given to their products (the geological record). There is a careful emphasis on observation, description of information and procedures of science. Regional studies lost importance to processes at large and to global scales. In the ESCP curriculum the history of science is quoted many times.

The view of science conveyed by geoscience tendency is of a universal science, strongly supported by works of great scientists with concepts being constantly improved. It is a dynamic and changing science, forever challenged by a search for the truth. The application branches receive minor importance. However, certain problems, not common in geology teaching at that time, are analyzed, as example, the degradation of water quality. Materials for active teaching are presented as well as manual and lab activities to stimulate student participation. The contents are reinforced by repeating themes and by gradually increasing the complexity of the topics.

At the same time of the advent of geoscience, other works with a diverse perspective of introductory geology are launched. Textbooks, which emphasize applied geological science, can be framed as environmental geology textbooks as, for example, one organized by R.W. Tank, *Focus on environmental geology* (1973). This tendency seems to search two sets of contents – subjects dedicated to natural hazards (earthquakes, volcanoes, floods, mass movements, etc.), and subjects on environmental impact (environmental impact of mining; mineral, energetic and hydrologic resources; and engineering geology). All of these topics receive a considerable amount of attention by the physical geological trend at that time. The classical topics of geology become peripheral on the environmental geology trend. They are only discussed when there is a need to explain applied phenomena. Unusual themes, such as medicine and population growth, become important. The textbooks utilize these themes to discuss the global crisis of the environment.

Some authors, by combining geoscience tendency with environmental geology, end up creating an environmental geoscience. The best example and the most persistent authors on this topic are A. N. Strahler and A. H. Strahler with their *Environmental geoscience: interaction between natural systems and man* (1973; a newer version of such book is entitled *Physical geography: science and systems of the human environment*). However, the basic idea to value processes of the atmosphere and of the hydrosphere gives importance to subjects not discussed by environmental geology.

The image of geological science conveyed by the environmental geology trend is of an applied science. It stresses two issues:

a) The environmental impact of human activities must be minimized; and
b) Human societies must be ready to face Nature challenges.

These issues are also presented by environmental geoscience. However, this science tends to separate human activities from natural processes to some extent. The applied science conveys a more realistic view of science because it suggests

that scientific activity is a human necessity and many challenges are originated by technology. Besides, scientific knowledge does have an impact on our daily lives.

These pedagogical materials rarely discuss ways for teaching science. The teaching approaches are linked to a passive transmission of knowledge. Therefore, the stress is still on technical terminology. Nevertheless, some authors do try to expose the knowledge by means of processes and products.

From the acceptance of Drift by most geologists during the sixties (Le Grand, 1988) to the nineties there is a consolidation of the theory of plate tectonics in the western world. This subject became obligatory in every introductory geology textbook. Thus, different themes and phenomena of introductory geology had to be reinterpreted in these textbooks as well.

In the nineties, a certain convergence among thematic trends is noticeable. Textbooks for introductory geology show some themes in common. Today, almost every textbook has included the processes of the modern atmosphere and hydrosphere. It is due partially because the consolidation of the plate tectonics theory and the advances of the planetary geology. Almost every textbook has now a chapter on space science as well as on applied topics, such as environmental impacts and natural hazards. General problems of our environment, global challenges, etc. have received a relative importance in every textbook. In spite of this apparent chaos, here is an effort to deepen the thematic relations and to present the Earth as a whole.

The global environment has a long temporal history and its relationship with social, economic and political activities can achieve an integrated treatment. This is an approach usually labeled as Earth system science (as the book by Mackenzie and Mackenzie, 1995). This approach searches to treat the processes of natural spheres and their links with applied elements of geology. It pays special attention to the biogeochemical cycles of Nature – their respective time, space, dimension and the economic and the political scope that can impact changes on trends of the development of Nature. The biosphere and its limits are the core of the approach. The big societal phenomenon receives the same attention (global climatic changes, changes of greenhouse effect, acid deposition, soil conditions, etc.). In sum, the global approach is stressed using the regional aspects to exemplify phenomena and transformations.

The image of geological science that is conveyed by the Earth science trend is the intensive interaction among social economic processes, the definition of political guidelines and the understanding of the natural processes. This trend presents a more realistic view of science. It greatly emphasizes ethical aspects of the philosophy and the history of science. However, it gives comparative little attention to other aspects of the same topic.

6. GEOLOGY AS A HISTORICAL, HYPOTHETICAL AND NARRATIVE SCIENCE OF NATURE

The studies of the Earth are different from other natural and experimental sciences. If we compare the study of physics with the studies of the Earth, we see that they are similar in the inductive and deductive procedures, in the experimental basis, in

the mathematical approaches, and in the synthetic and analytic thought. However, they are quite different when working with practical and theoretical problems of Nature because the temporal processes play multiple interrelations. These features are common in the studies of the Earth system. Geology studies require a *minor* reasoning when compared to physics studies (multifactorial thought, analogical reasoning, abduction, historic and comparative procedures).

The perception of these facts is a classical topic in geological literature. Thomas Crowter Chamberlain (1843-1928) explained in 1897 the singular character of these studies. Facing the impossibility of linear (verbal) language to present and to study natural phenomena, he suggested the need to investigate several possible hypotheses to understand each situation. He rejected linear reasoning as well as a restrict mode of inductive and deductive reasoning. Additionally, he defended the search for diverse causes of a fact. He named it the *method of multiple working hypotheses*.

At the same time, Grover K. Gilbert (1843-1918), in 1896, defended the need to learn from one's mistakes – a kind of learning that is crucial in the making of a researcher. The future scientist has as much to learn from his mistakes as from his findings.

The two ideas, Chamberlain's and Gilbert's, are significant because they were both dedicated to geology, scientific severity and criteria; because of the position they held – Chamberlain followed the footsteps of the great American geologists, wrote scientific reviews and became a faculty member of the University of Chicago. Gilbert was a member of the US Geological Survey staff (Pyne, 1976 and 1978). Their views, slightly different from each other, show the limit of the use of inductive and deductive scientific patterns, as well as the mathematical procedures in geology. It can be inferred that they suggest that the historical explanation, essential to discover mineral and energetic resources, needs other methodological procedures (Spencer, 1997).

There are several contributions to nature from the Earth sciences during the twentieth century. In a broad overview, we can divide them into two large groups. The first defends the idea that geology works with the same theoretical tools that physics does, despite their differences. In other words, geology works with inductive and deductive methods, mathematical models and analysis. It also postulates that this kind of reasoning may be limited in parts of geology (for instance: Kitts, 1977 or Gould, 1965). The second group defends that geology is a particular scientific branch in which physics reasoning has a limited use. These groups try to show the synthetic and historic character of the geological thought (for instance: Potapova, 1968 or Frodeman, 1995). We favour the second group, as long as the study of the Earth system performs a particular and different synthesis. It differs from other scientific branches. From this point of view, experimental, mathematical and inductive-deductive approaches are very restricted – they do not broach temporal and historical problems. It is important to point out that specific and specialized branches of geology allow for reasoning similar to physics'

reasoning. These tools are very useful in specialized areas. However, when thinking about scientific literacy or global understanding of the Earth, we must search for an integrated view of the planet.

A distinction made by Simpson (1970) clarifies the approaches of geological science. He distinguishes two kinds of geological studies. In the first one, geology is a historical science that studies singular configurations. In the second one, geology is a non-historical science that searches for processes, which have general regularities that must be valid whatever happens in any place, or in any era.

This analysis of geology allows for the understanding of certain characteristics of geological textbooks. It also stresses some relevant elements for geology teaching. The common distinction between physical geology and historical geology, presented in some textbooks, corresponds to a specific trend of geological science. In other words, it conveys the idea of a double character of geology – sometimes geology is a historical science, other times it is not. As a historical science, geology needs to treat singular cases. Therefore, it stresses regional examples. Emphasis on geological records seems to find certain coherence when exploring singular facts.

In 1968, Potapova argued that geology was in a moment of crisis despite its practical success. The crisis resided on confusion between the subject matter and the immediate matter of investigation. The subject matter of geology is the whole Earth and all its temporal processes; in other words, it is the cosmic evolution of the planet. On the other hand, the immediate matter of investigation of geology is the crust – the main source of information about the Earth history. Many geologists take the crust as the subject matter of geology, thus making it difficult to understand that geology is a historical science of Nature unlike other sciences. For example, in chemistry one can study the crust without the historical perspective.

Thus the great theoretical problem of geology is the establishment of the general processes of temporal (historical) development of the planet, the characterization of trends of this natural development and to foresee the future course of terrestrial transformations. This task requires the study of current processes and their products. By analogy, this task also requires the comparison of current products with geological record in order to interpret the origin of codified marks.

Potapova (1968) recognizes a specific character of the studies of the Earth that allows us to get important aspects of the historical studies of Nature. The historical-comparative method, to transfer information from the present to the past, is strongly based on analogy nexus and on visual observation of phenomena. As it is limited or impossible to get the experimental proof for the predictions (retro predictions) on the past of the Earth, the historical models and explanations are hypothetical (Gruza and Romanovsky, 1975).

The visual language, used to represent models and explanations, occupies a relevant role in geology. In order to understand the planet it is necessary to generalize the use of visual diagrams – mainly the geological map (Rudwick,

1978). If we try to combine these considerations on language and communication, we are led to value the narrative (verbal) and the visual communication to read the planet globally.

It seems worthless to divide geology into a historical and a non-historical science. The historical approach is needed to understand the interaction of the studies of the Earth. This historical study must treat current phenomena and their products as a result of the interaction of the natural spheres as well. In other words, the history of geology suggests that the studies must be oriented to the understanding of the whole planet and the temporal interaction of its material spheres.

Regional studies deserve emphasis when they are viewed in relationship to the general processes of the development of the planet. The political arena must consider these regional and global scales in future decision-making. Such requires an understanding of natural, social, and economic implications. A corollary of this point is the choice between an approach on classification or on interpretation of the geological record. The geological record (distribution of rocks, minerals and structures) is a special code (a system of signals), which needs to be interpreted to understand the processes. This gives focus to the study of characters of natural specimens.

Anguita (1996) and Mayer (1996) argue in the same direction: the Earth should be studied as a whole. This is done by means of the integrated studies of spheres together with plate tectonics while following a systematic approach. As a consequence, geological studies are not to be primarily descriptive.

Finally, the history of geology together with an epistemological approach helps us to collect important elements from different trends of geological teaching. In addition, for the undergraduate teaching level we can have a reference of contents, activities and skills to develop.

7. QUESTIONS GENERATED BY SCIENTIFIC LITERACY

Geoscientific literacy refers to a search on erecting a civic dimension to the scientific knowledge. There is an agreement on the need to approach the scientific education with this aim. The divergence is concentrated on *how* we can do it.

The following bibliography on science education supports the importance of developing the nature of Science in teaching (Matthews, 1997; Hurd, 1998); the relations among science, technology and society (Solbes & Vilches, 1997); the interdisciplinary projects and themes as developed by the teaching of science (Cuello Gijón, 1988; Amaral, 1995). Nevertheless, it is difficult to have a consensus on the following problems – to delineate theoretically the role of history and philosophy of science in teaching, the role of science, technology and society or, even to say exactly, what to develop a conceptual teaching is.

There are many ways that seem to offer a good chance of success. Bezzi (1999) or Chalmers (1999) obtained good results from the use of history and

philosophy of science. When talking about scientific literacy, the differences are significant, too. Robinson (1998, a manuscript dated 1965) made a detailed exposition of scientific literacy; he argues that it is not enough to defend a conceptual teaching of science; students need to understand the processes and products of science. In fact, he asks for a need to characterize the nature and the structure of scientific knowledge. He advances a list of aims that can clarify these quoted elements and to guide the formulation of curricula and programs.

Robinson (1998) exposes his aims to scientific literacy and demonstrates the existence of two kinds of experimental science (correlation and exact sciences). This point is significant because it offers a promising source of reflection on Earth sciences. In other words, he reinforced, before Potapova (1968) and Frodeman (1995), the historical nature of certain parts of the experimental sciences. Consequently, geology is a science marked by procedures of collecting and comparing data. Despite our concordance with Matthews' (1997, p. 306) criticism against Robinson (that has followed the logical empiricism), we still agree with the idea of students adopting nature of science. But only if it is allowed as part of an integrated view of the world, replacing the former "layer cake curricula", as put forth by Mayer and Tokuyama (2002).

All historical and philosophical approaches are marked by options. Mayer and Tokuyama do not stress just the importance of studies on the Earth but the focus on its integrated systems. From these claims, some kind of philosophical and historical approach to science is inevitable to review curricula and programs. Keeping these limits in view, some guidelines formulated by Matthews (1994, p. 49-50) can be followed on. History promotes a way to build educational concepts and philosophies of science that can delineate the best view for the organization of science.

Bezzi (1999, p. 694-5) defends the positive side of Earth sciences as a science. The interpretative and narrative character of geoscience can give access to science and achieve the goals of scientific literacy. Narrative logic provides the understanding necessary to a knowledge that lacks certainty. The global changes are an example of that. Interpretative aspects are necessary to treat problems intrinsically vague, resistant to quantification or reliable prediction like questions on resources, hazards, environments, etc. From this kind of reasoning, produced by geoscience, people must acquire to understand the Earth system and its great challenges. These considerations lead us to attribute special value to applied aspects of geology as important aids to understand environmental problems.

8. MAIN THEMES AND SKILLS FOR STUDENTS OF THE UNDERGRADUATE LEVEL

This set of topics and subjects are useful to look for a combination of relevant approaches to delimit a subject matter aiming to obtain an image of geologic science, concepts and skills that may allow interpretation of the whole planet – its parts and the integration between global and regional studies (Fig. 1). Our choice is to emphasize certain relevant aspects from each of these tendencies. This is made under considerations of the teaching of science and geology as a historical science.

In an undergraduate course, these themes help emphasize some principal points: (1) they reveal the structure of scientific knowledge and the fundamental elements of geology (comparative thought, actualism, visual language, hypothetical and narrative knowledge): (2) central concepts that, by means of theory of plate tectonics, reveal the systematic organization where all spheres interact. The thematic structure (Fig. 1) is guided by the following elements:

a) The epistemological approach on the studies of the Earth;

b) The study of global processes (natural, artificial or links between Nature and society):

c) The study of aspects related with engineering geology or other environmental studies;

d) The nexus between processes and making of decisions for the future by human society.

Discipline overview

Earth System Science I

Subject: The study of the different Earth spheres
The present configuration of the Earth's surface

Main Topics
The foundations of the Earth studies
Geosphere
Interaction of the fluid spheres
Biosphere and the interaction with the other spheres
Geosphere and the human systems

Earth System Science II

Subject: The relationship of Man-Earth Spheres
The World System helps shaping the Earth's surface

Main Topics
Geosphere and World System
Introduction to the study of the World System
The Memories of the World System
World System as a work and as a norm
The inequalities of the World System: Planetary regions

Figure 1. The main aims of the two successive Earth system science disciplines

The themes aim to consider the precedent analysis and, by means of its development, translate the process of production of the Earth science. The contents are treated by means of an approach to mark certain understandings.

The central role of research is to investigate the multiple interactions of the terrestrial environment; to articulate the ideas of investigation, doubt and uncertainty of science; to apply an interdisciplinary approach to discuss social activities on the terrestrial surface; and to mark the hypothetical character of the knowledge on the planet. The main skill to be achieved by this is the ability to

interpret facts, phenomena and coded information on the whole Earth and its connections with regional happenings.

9. DISCUSSION

The convergence of analysis from diversified sources (historical, epistemological and educational) leads to a set of points, which characterize the Earth Systems Science to the undergraduate level. These points are interrelated by the central idea of the nature of Earth science system.

1) To understand the nature of the studies on Earth science systems: This implies the limits of theories and models, to know the past and the future of the planet.

2) To understand the movement towards knowledge on the planet and the process of development of the studies on the Earth. This implies understanding the fundamentals of the Earth sciences, their principles and the way they are applied; the structure of classification and its nexus with genetic interpretation; the relationship between regional and global aspects and the interaction between these studies; and the applied branches of the Earth sciences in different scales of space and time.

3) To understand that some geologists allow inductive-deductive reasoning, synthetic and mathematical models in their work. This implies to understand that classification, comparative studies, actualism, and historical interpretation are different kinds of scientific procedures.

4) To understand that the Earth sciences are made by trained experts – geoscientists who create concepts, models and representations in reality. This implies an understanding that the scientific knowledge on the history of Nature can be checked out and our current wisdom will be changed in the future due to new data and new theories. This process of making knowledge implies to select criteria and to attribute meaning to natural objects. These mechanisms permit us to know reality. Therefore the Earth sciences are a result of observation theoretically oriented and that they have a practical warranty because of the success of their forecasts.

5) To understand the main concepts and theories to study the temporal interaction of terrestrial spheres and the whole Earth. It implies an understanding of the theory of plate tectonics, notions that order the theory, and its implications to understand the Earth system.

6) To understand the relations between Nature and society. This implies an understanding that the Earth was not created for us (Mayer et al. 1999).

7) To understand the Earth as a system of long temporal duration. It implies an understanding that the Earth exchanges matter and energy with space; that it is decisive to keep the ecosphere; and that stable climatic conditions were decisive to mankind and civilization.

8) To understand that the relationship between mankind and nature involve different scales of time and space and the related changes interfere with regions or the whole world.

10. CONCLUSION

Earth System Science is relevant in the preparation of skills that can treat information both on the environment and on the planet. Learning the Earth system science allows us to enlarge the horizons of future geography, geology and science teachers. It helps to develop skills concerned with scientific literacy, what may also be called a *geoscientific literacy*. It poses an important challenge for college

programs because it requires a way of teaching that considers the interdisciplinary potential of the Earth studies, as defended by Cuello Gijón (1988).

Reviewing the history of Geology as a discipline allows us to see how it has been transformed into a broader Earth system science. From the reference of teaching of this discipline, we identified many points that helped to strengthen the structure, the scope, and the emphasis on epistemological changes.

An extensive bibliography on science education and on the Earth science teaching supports an approach for teaching science based on the relationship among history of science, philosophy and epistemology. Classic contributions are required to framework the central themes of the Earth system science knowledge, dated from the eighteenth century to the twentieth century. The historical development of the studies on the Earth was marked, many decades ago, by a disciplinary approach to identify mineral and energetic resources. It became more ample, dynamic and integrated as it included the hydrosphere, the atmosphere and the space studies as well as their interaction with the Earth systems. The history of the Earth, biosphere and mankind were also considered. After the adoption of an integrated Earth system science, a number of disciplinary questions became, during the last ten years, interdisciplinary problems facing the study of the Earth systems. The Environmental Education grew out from these problems and inserted some new topics in the Earth studies, in spite of the fact that many problems regarded as environmental are best described as social and economic problems caused by the progressive unsustainability of the present social-economic model (Folch i Guillén 1999).

Some changes have been introduced by the Earth system science to the perspectives, contents, scope and structure among sciences. The Earth system science have also added to and changed the interactions among science, technology and society (STS). Moreover, the Earth needs to be seen and studied as an unit, an unit that has a long history, many environmental changes, ecological processes and cycles which need consideration before decisions are made on environmental changes, natural hazards and the future of the human welfare and civilization. College students should be able to analyze, describe and understand the significance of natural hazards (earthquakes, floods, etc), environmental impacts (e.g. the results of new technologies) and natural resources (e.g. management of water supplies and energetic sources). The geoscientific literate student would learn new information on these topics and help to take part in educating citizens for present environmental challenges and future geologically conscious societies.

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CHAPTER 15: UNIVERSITY AND PUBLIC SCHOOL PARTNERSHIP FOR TRAINING SECONDARY SCHOOL TEACHERS IN GLOBAL SCIENCE: A BRAZILIAN EXPERIENCE

Maurício Compiani and Silvia de M. Figueirôa, State University of Campinas, BRAZIL

1. INTRODUCTION

This chapter aims to discuss some features of the on-going training of teachers, relating them to Global Science Literacy, and it is based on the experience developed between 1996 – 2000 within the project "Geosciences and the on-going training of teachers active in secondary education". This project was financed by the following Brazilian funding agencies: FINEP (Studies and Projects Funding Agency), FAPESP (the Foundation for Research Support of the State of São Paulo) and CNPq (National Council of Scientific and Technological Development).

The project is one of the activities of the Department of Applied Geosciences (DGAE) of the Institute of Geosciences of the State University of Campinas (UNICAMP). The research was carried out among secondary school pupils of the 5th to 8th grades (11 to 14 years of age). The activities sought to deal with the teaching and learning problems that had been detected, more specifically those linked to topics of Geosciences. We use the term Geosciences to cover those contents of Geology, Astrology and Meteorology, among others, that do not figure as a discipline in secondary education, but that are dealt with in Geography and Sciences. We also include many contents of Geosciences that were previously only dealt with in Physical geography and which today are in Sciences, such as Pedology, Climatology etc. The project was focused on the teacher and prioritized his activity in the classroom, involving the on-going education of teachers along two complementary lines: the training of the working teacher-researcher and the constructivist orientations of the teaching-learning process in the classroom. It was a project of collaborative research between university and public school, based on action research approaches to foster the interactive-reflective process as a favored condition for teacher training and development. The research team was organized as follows: by the University - 3 professors, 1 Master's student, 3 undergraduates with scientific initiation scholarships; by the Paulo Freire Institute (NGO) - 1 researcher; by the public school – around 15 teachers.

One of the main questions under debate in this chapter involves the relation of human beings with nature, for as we see it, any approach which favors a more integrated approach to the planet cannot avoid the discussion of the 'humanization of nature' (transformation of nature by human activity) and the 'naturalization of human beings', the latter being far more difficult to understand as it involves understanding the metamorphosis of the natural human limited by his condition of a universal natural human being - a point of view based on Srour (1978), who based himself on Marx. Both the training of teachers and the relationship between human beings are, notwithstanding, fairly complex issues in themselves. Our challenge

consists of dealing with them, and, even more daringly, attempting to integrate the most practical facet, that is teacher training, with an epistemology that seeks a global science.

In the present state of globalization, technological domination and socio-environmental crisis, we believe that there are some principles for education that need to be formulated and put into practice at the most global level possible. Some of these principles which acted as guidelines in the project "Geosciences and the on-going training of teachers in basic education" are as follows: i) education is a right of every person, and we are all apprentices and educators; ii) education is individual and collective, and has as its aim to shape citizens with a conscience of their immediate surroundings and of their planet, who respect the self-determination of peoples and the sovereignty of nations; iii) education is ideological, not neutral; it is a political act, based on values aimed at social transformation; iv) education should enable all persons to deal with conflicts in a just and human way; v) education must encompass a holistic perspective, focusing on the relationship between human beings, nature and the universe in an interdisciplinary approach. To be more precise, it seems to us that many people agree with the goal of seeking the integration of environmental and developmental concepts, including demography, in all educational programs, with an emphasis on the critical dimension of the causes of environmental problems in a local context and their connection with global issues, the link between the political, technical and scientific data available for the understanding of problems and the development of training and re-cycling of those responsible for political decisions at all levels.

The project "Geosciences and the on-going training of teachers in secondary education", stimulated by various texts, especially that of García (1987), adopted some ideological bases for its educational conception, which will be briefly discussed below. Some of these topics will be taken up again throughout the text, whereas others will not because the discussion of each deserves another paper at least. In sum, we are assuming that i) with regards the technical-specialist educator, it is necessary to train the investigating and reflective educator; ii) with regards the hierarchization and centralism dominant in the school structure, an interactive model is proposed that can cope with the horizontality and polycentrism needed to treat socio-environmental problems; iii) with regards the fragmentation and specialization of knowledge, an interdisciplinary approach that covers the focuses of globalizing and integrating teaching-learning is proposed (Compiani, 1996a); iv) with regards individualism and competition, the proposal is to investigate reality based on the confrontation of hypotheses, on group work and on attitudes guided by ethics and solidarity; v) with regards the decontextualizing of knowledge acquired in school, theoretical-practical activities are proposed, based on field work, focusing dialectically on local/global, specific/general and that which can be generalized/historical (Compiani, 1996a); vi) with regard to a model which encourages passivity, the active construction of knowledge, action, and the participation in decision-making for the solution of problems that have political, social and environmental implications are proposed.

These assumptions, and the need to make them operational to ensure the training of teaching staff, lead us initially to the discussion on the conceptions of

nature and education, which involve: new attitudes and values with regard to the relations human-beings-Earth; geology as a historical science, interpreting and encompassing nature; revitalizing field work; school as one of the social environments for the construction of knowledge. Following on from this, we shall try to give concrete examples of how such aspects were treated in the project.

2. NEW ATTITUDES AND VALUES CONCERNING THE RELATIONSHIPS HUMAN BEINGS-EARTH

In Brazil, the nature/environment are not a cultural value because historically, there have been vested interests aimed at masking and camouflaging. For us, this is the starting point of our discussion: to understand that to build new attitudes and values in relation to the environment implies understanding that the environmental crisis is not a fact restricted to the scientific or technical field, rather it is an eminently political question (Paschoale, 1989). This is because the appropriation of nature is carried out according to the scientific knowledge we have about it, but it is not limited to this knowledge. Various other equally or more decisive sets of values which lead to appropriation by human beings also come into play: affective, aesthetic, ethic, conceptual, religious and ideological values. Paschoale (op.cit.) puts technical knowledge into a relative perspective, emphasizing that:

> the appropriation of nature is nothing more than the projection of this system of beliefs onto it – the set of values that encompasses even the very conception of Science – a projection which at the same time tries to legitimize this set of beliefs. (p. 128)

We can complement the theoretical basis that supports the discussions and decisions related to the socio-environmental problems with the ideas of Ab'Saber (1991), who states that, for this, we need a clear understanding about the projection of Man on earthly spaces, inherited from nature and from history; about the place of each one in the remaining spaces of modified Nature; of the place of each one in the social spaces created by the socio-economic conditions.

The socio-environmental crisis forces us to an understanding, the clearest and most global possible, of the interdependence of society and nature. Geology has an important role among the sciences to form a view of nature which is encompassing, historical and organic since, due to its being a specific type of rationality that explains the planet, it helps in the understanding of the dynamic of the interaction of human beings in their habitat. This allows the pupils to become aware of the history and development of the planet, also permitting them to think about the interests and role of human beings, socially organized, in the transformations of the environment (Paschoale 1989; Compiani & Paschoale, 1990).

Our main object in using geological knowledge in any level of education is to structure a conception of nature, of environment as a long process of development of which the sphere of social organization (the noosphere) is a part. Geology has an important role for the understanding of the process of alteration of this environmental " *modus operandi*", through the perception of the qualitatively different role that the noosphere has been developing as it modifies,

creates/destroys, as it constitutes terrestrial processes. Human work, expression of the noosphere, is a powerful geological agent. According to Paschoale (1989), work and knowledge carry out the appropriation of nature, and in doing so, recreate this nature. Any appropriation is included in the evolutionary course of the planet, since it acts upon natural processes that develop at certain rates, intensities and speeds. The resulting transformation (recreated nature) is constituted in such a way within the process of historical development of the planet that it becomes another, even if at the time we do not perceive the transformation as it happens. The appropriation of nature by human beings has a decisive influence over the general developmental process of the planet, since each and every change in environmental design must be focused under the perspective of historical development. For this reason, after each new development and understanding of the phenomena produced by natural agents, the history and forecasting of future phenomena is re-interpreted.

We must be especially sensitive to the questions of nature and to the improvement of society. To guarantee the existence of a healthy environment for all humanity requires a really encompassing conscience-raising, that can only resound with an educational process that involves ethics, moral, ideology and science and a renewed philosophy of life.

3. GEOLOGY AS A HISTORICAL AND INTERPRETATIVE SCIENCE, ENCOMPASSING NATURE

From 1960 onwards, in the science curricula, there has been a centralization of the focus of interest on the structure of science, scientific knowledge and scientific method and very little has been discussed or experimented in relation to the applied, technological and cultural aspects of the sciences (Caamaño Ros, 1988). A swift change has taken place in the curricula since 1970, in the direction of understanding science as a human activity, increasing the emphasis on comprehending what the scientist does, in social, political and technological terms (Hodson, 1985; Matthews, 1994) and particularly on the public responsibility of the sciences in view of the gravity of current socio-economic-environmental problems (Solbes & Vilches, 1989).

In the teaching of Geology and Geosciences there has also been a broadening of approaches in this direction, however, the attempts are often pragmatic and reductionist as they lack a more solid theoretical-methodological base. Moreover, they are too specific, for as can easily be seen, the great majority of the works on Philosophy (and also History) of Science had as a basis the physical-mathematical sciences, erecting them models for scientific development. We are of the opinion that these new educational experiences must be founded on the epistemological analysis of the internal structure of Geology: students need to learn the fundamental concepts, their explanatory value and their function within the "architecture of Geological Science". There is a "geological line of thought" which does not follow the binary logic we are accustomed to and which is reinforced by the teaching of traditional sciences. As was clearly expressed by Seddon (1996), a renowned practicing geologist:

> the thought processes are fairly typical of a geologist's response to surface phenomena: look for an explanation [of day-by-day questions] from earth history. (...) geological debates are quite often combinatory rather than excluding. (...) A geologist likes to keep all his options open, and is trained to do this. Geologists would welcome stunning successes, but if each step relied on rigorous exclusion, few steps would be taken.

On the other hand, in the historical and sociological analysis, which allows a better connection between teaching and real problems so as to shape students to take an active role in society, it is necessary to express the deep relations between science, technology and the social/natural surroundings, relations that must be placed in a historical context. It must be made clear that modern science, which reshaped our view of the post-Renaissance world and that continues to influence our lives to the present day, emerged in a given historical time and space. The contexts of its emergence and of its later evolution gave it its character of productive (and destructive) force, capable of revolutionizing production methods and, on the other hand, of provoking environmental alterations on a planetary level (e.g. the greenhouse effect). At the same time, the expansion process of modern science to contexts outside Europe (and even to the peripheries of Europe) stamped it with the imprint of compulsory – and often difficult - dialogue with the pre-existing local culture and wisdom. This enriching discussion with regard to the processes of expansion and "acclimatization" of European science in non-European contexts is long and complex, and is not within the scope of this chapter (see: Figueirôa & Lopes, 1996). This debate is made even more important if we bear in mind both the premises of multicultural education in democratic (and multiethnic) societies and the challenges of science teaching in countries located outside the North Atlantic axis.

From the collision between epistemological and socio-historical analyses, a path of reflection and educational efforts, of which we as yet know very little, can be opened: the role of the social sphere, which along with other inseparable factors constitutes the general historical-geological process of the Earth. It is the role of Geology to contribute to the appropriation of materials, debating it, according it values (ideological, moral, ethic, etc.) and evaluating its social and environmental consequences.

Geology has an important role in forming a broad, historical and organic view of nature and to contribute to the teaching, in the Universities training new professionals as well as in schools, shaping the common citizen, because a clear understanding of the globalizing processes and the interdependence of Society and nature is necessary for both. Many examples can be quoted here, such as the regions of systematic flooding in the city of São Paulo due to unrestricted urbanization from the 1930s onwards of the valley floor and flood plains of the two great rivers that cross the city. To back up this text, it is worthwhile quoting Seddon (op.cit.), who concludes on remembering, among many others, the case of the huge architectonic and urban planning differences between New York and Tokyo, conditioned by the rock substrate:

> a knowledge of earth history can greatly enrich our understanding of human history. (...) The history I learnt at school was about the human actors on stage, almost entirely ignoring the stage itself, the

> setting in which their actions took place, and by which their actions were often deeply influenced. Human history without environmental history is partial.

In practice, we are adopting a more encompassing view of Geology, seen as a historic science of nature (Potapova 1968, Paschoale 1989). This view holds that the historical-geological processes are so important in uncovering the evolution of the planet as well as in understanding the present and future configuration of the crust and the Earth. Thus it seeks to understand the great importance of the social sphere in the present and future configuration of the planet. This conception of geology has considerably helped in the recent attempts to treat the Earth as a whole, approaching it under the focus of Earth Science according to two great integrated perspectives: system-process world, for the geographical aspects and system-process Earth for the geological aspects. Founded on different theoretical conceptions, this view is nevertheless not very different generally speaking from the system sciences approach for geological sciences, as set out by Mayer & Kumano (2002) and defined by the Earth System Sciences Committee

> In the system sciences, since controlled experiments are impossible to construct, history becomes crucial and a 'different set of criteria for what counts as an explanation' must be used. One of these is the use of reasoning by analogy (...). A second challenge is identifying and defining the object of study. (...) Finally, 'the historical sciences are distinguished by the decisive role of narrative logic in their explanations'. (...) The concept of the Earth as a system (...) provides a holistic view of science and of the earth system, a view that includes people and their interactions as integral components of the earth system.

In our opinion, the human sciences are fundamental in this approach as, according to Ab'Saber (1991), they provide certain articulated knowledge about the region which serves as support for the human inhabitants, human-being producers and human beings integrated in certain socio-economic conditioning factors. This approach involves all scales, starting at home. It touches the street and square. It covers the neighborhood. It encompasses the city or Metropolis. It goes beyond the periphery. It re-thinks the pockets of poverty. It reaches the regional peculiarities and diversities. In order to later integrate national spaces and thus to collaborate with the different levels of sanity demanded by the planetary scale, which nurtured life and gave rise to the basic attributes of the being who think about the Universe.

From another point of view, the environmental problems have been posing enormous challenges which to be overcome, or at least faced, must necessarily pass through the training and information of citizens at different levels. The Geosciences, dealing with the global understanding of terrestrial processes, whether they be past or present, as well as with the search and exploitation of mineral resources vital to society (water, industrial minerals, metallic minerals, fossil fuels, etc.), play an important role in the shaping of citizenship and, consequently, of an environmental conscience. At the same time, and no less important, education in Geosciences goes beyond the fundamental debate between Science, Technology, Society and Nature, even historically and theoretically, broadening the development of the "scientific culture" of individuals, essential for the full exercise of citizenship in contemporary societies.

A scientific culture is necessary, above all nowadays when our society is beginning to recognize the problems of the unrestricted continuity of economic growth. According to Frodeman & Turner (1996), in current public debates, the view of economic growth competes with a variety of other views, such as human health, cultural diversity, conservation of the bio-diversity and natural beauty. In this way, the role of professionals in Geology is changing: e.g. instead of merely providing objective data for mineral exploitation, these professionals are frequently called upon to evaluate questions (mitigation of geological risks) to which the answers are neither clear nor objective, involving conflicting scientific, economic, political, ethical and aesthetic values.

4. REVITALIZING FIELDWORK

In the local/global relationship, so necessary when dealing with the socio-environmental problems, there is a saying that bears remembering: "think globally and act locally". Naturally, nowadays we must also act globally as a series of environmental problems occur on a scale that affects from some countries, continents to the planet as a whole. Unfortunately, a series of educational projects, mainly aimed at urban problems, still only deal with local problems without taking into account global problems. For the coming millennium, we need to build citizens-as-leaders, who have an interdisciplinary vision and who know which discipline(s) to focus on in order to solve given problems and situations. It could be said to be the dialectic of disciplinary with interdisciplinary. It would be global thinking and an ability to act locally and globally. Moreover, these citizens would know how to mediate between cultures, academic and lay knowledge, values, between interests and visions of the future.

The local/global relationship needs methodologies of environmental studies and fieldwork. According to Santos & Compiani (1998), fieldwork can be used in teaching as a strategy in which everything can be part of a larger process: the holographic effect, where all the parts contain the whole. The idea is to confront the dominant fragmentation of knowledge, which blocks the mechanisms of analysis of real problems, as it does not facilitate the relation of concepts, procedures and attitudes dealt with in different subjects of the curriculum. Through fieldwork, the geoscientific category "place" is understood as the locus of junction with the whole, a subtle interaction between particularity and generalization.

For Santos (1997: 273), place is increasingly "the object of a global reason and a local reason, co-existing dialectically". Global space is in the world and in the place and local and global space comprise the world and local hologram. Nowadays, the place takes on a new dimension and is understood as

> a meeting point of logics that function on different scales, revealing diverse, sometimes contrasting, levels, in the search for efficacy and profit, in the use of technologies of capital and of labor. The place is the meeting point of interests, both distant and near, world and global (Santos, 1994: 18-19).

Attention to the place, according to Kincheloe (1997), brings the focus onto what is particular, but in the sense that, contextually, it is based on a greater understanding

of the surroundings and the processes that shape them. The sense of place sharpens our understanding of what is concrete, singular and historical but, all together, sharpens the understanding of what is abstract, of properties, of the historical process and of nature. In sum, fieldwork is the locus where dialectic and the hermeneutic circle are constituted (see Frodeman, 1995), between the parts and the whole, what is particular and what is general, what can be generalized and what is historical. This dialectic character emphasizes the integration of everything (the historical development of the Earth) and its parts (processes, constituting spheres, structures, fixtures, etc.), as well as the organic aspect of knowledge, since the very constitution of totality has its genesis and historical development.

The field is the context itself in which the observer can presuppose its sense, which is a key element in the construction of the geoscientific (and biological) way of thinking. The facts only make sense in the context created by other facts. The facts are more than bits of information: they are part of a wider process. Conscience must be understood as part of a greater process. For this reason, the perspective of a more encompassing approach of global science must necessarily revitalize research in the field by both teachers and pupils. With the support of Ab'Saber (1991), this perspective demands, more than ever, method, notion of scale, a good perception of the relations between time and space, an understanding of the social structure, knowledge of different regional realities, cultures and distinct language codes adapted to the previous conceptions of the pupils. Moreover, it demands that the value of the multiplicity and diversity of the various "worlds" that co-exist in our societies be respected and believed in. It involves the permanent exercise of interdisciplinarity and facing daily issues. It questions the old disciplines in an attempt to perfect new theoretical lines of thought to achieve a broader understanding. It paves the way for the conquest or reconquest of citizenship.

5. SCHOOL AS ONE OF THE SOCIAL ENVIRONMENTS FOR THE BUILDING OF KNOWLEDGE

A synthesis of part of Bernstein's ideas (1997) shows us research which is more closely linked to the foundations in the field of sociology of education which constitute empirical studies of the school seen as a organizing structure with interactive practices, in which the curriculum, pedagogical practice and the means of evaluation set out the terms for the crucial meeting between teachers and students in the context of the classroom. For this author, there are new studies focused on language, in the context and regulating and negotiating practices that take place in the classroom. There is less concern with the way in which the regulating discourse, distribution of power and the principles of power are established, and a greater concern with how to articulate the principles of communication and the interactive practice within the local context of the class.

This initial synthesis is basic because our studies in the Geosciences' project are primarily to be found in the field of communication principles and regulating and negotiating practices that take place in the classroom, and less in the discussions of power regulation. Within this field, our idea of understanding the school as one of the social environments for building knowledge also attempts to

comprehend and improve the mediating role of the teacher, the contributions of the pupils and the discourse inherent to the classroom. The teacher should be the agent of the intended changes in the pupils' learning, concerned with articulating the content with the historical reality of the learner and with putting the teaching plan into context so that the pupil might analyze and transform reality. However, these are actions that demand of the teacher a reflective attitude towards his practice. This attitude, as Lüdke (1995) states, gives the teacher the opportunity to participate in the knowledge that is elaborated and re-elaborated each moment or, in other words, the teacher should be the researcher of his own classes, of his own process of action.

The boldness of our objectives is in that the teachers, in partnership with us, develop practices, know-how, activities and materials in the classroom and undertake educational investigations on their performance in the classroom. In other words, we seek to elaborate a sort of 'curricular proposal', which would involve a training process of the teaching staff, by means of the investigation that the teacher himself makes of his pedagogical assumptions, of his performance in the classroom and the consequences. We need to give value to the activity of teaching by highlighting the practical-reflective focus of his didactic activity. This means re-dimensioning the conception of the teacher: his task cannot be merely that of a technician who applies ready-made recipes made by armchair educators because what must be stressed is the singular, dynamic and variable character of each context: school, class and, also, teacher. Thus, a requisite of the teaching activity is that it undertakes investigation, in an open and creative way.

Another crucial point is to create, among teachers, a cultural school atmosphere of learning to observe and of learning from the communities, incorporating the cultural resources that the children bring to school. This is not easy. The teacher needs to have a great capacity to feel and hear the conceptual elaborations of his pupils in order to build up a guidebook, which allows him to take on the role of interpreter. The role of the teacher is crucial, for while basing himself on the process of the pupil and at the same time guiding him towards possible syntheses, he favors discussion, creates an atmosphere of listening to each other and of debate, ensures that each pupil fully explains what he is saying and discriminates the divergences as they appear. The characterization of the pupils as active and interactive subjects in the process of construction is appropriate but we cannot forget that when the context of this production is the classroom, the teachers are also important, not only as facilitators of learning but as mediators of scientific and every day views, both their own and their pupils.

For this reason, we need to research the relations between scientific discourse and narrative in the classroom, and how certain particularities of the classroom (previous ideas, mediations, discourse) and of the organization and structuring of scientific knowledge constitute decisive factors for the constitution of school knowledge.

According to Geraldi (1998), it is the valorization of the processes and practices of interlocution that make the pupil a capable pupil, and not merely the information he possesses. A teaching proposal that takes into account the enunciated event in the classroom and the relation of interlocution, of interaction, produces knowledge and produces discourse. There are several voices within the discourse of

the teacher and the pupils. The teacher needs to live the event. All this goes to show that we should give greater attention to the sequence of pedagogical work in the classroom, taking into consideration the event, the place, the context and the interactive process.

Alongside this, the project "Geosciences and the on-going training of teachers in secondary education" intended that the teachers should practice a general didactic strategy of a constructivist nature (Coll, 1991), which follows the principle of adjusting pedagogical help and can be carried out in multiple didactic methodologies. In each situation the teacher should opt for the adjustment of pedagogical help: he can provide the pupil with organized and structured information, or offer him models of action to imitate; at another point he can formulate more or less detailed indications and options to carry out some tasks, or even allow him to choose and develop, in a totally autonomous way, some learning activities.

If it is clear that within this constructivist strategy special attention must be given to the interactions and discourses constituted in the classroom, for according to Edwards and Mercer (1989), if it is the pupil who constructs significations and attributes meaning to what he learns and nothing, not even the teacher can substitute him in this task, and if the teacher introduces the pupil to the cultural context, then the teaching-learning process would appear to be mediated by the posture of the teacher and by the constructive mental activity of the pupil. This leads us to attempt to understand how the dynamic of conceptualization of the pupils is conditioned to the fact of being produced in interaction with the activities and the school discourse, where the intervention of the teacher is decisive.

In the "Geosciences" project, we endeavored to practice and investigate one of the points that Cachapuz (1997) considers crucial for the future development of the investigations in the Teaching of Science, which is to favor investigation focused on the classroom and of an ideographic nature. The idea is to give greater emphasis to studies that are typical of the context in which the teaching-learning process is being developed and to seek to treat researchers, teachers and students as real and social subjects and not as mere statistics. In particular, when dealing with the public school in Brazil, it became necessary to pay special attention beyond the statistics. To involve it in research projects requires funding that can cope with all the complexity of problems that besiege it, problems varying in scope, some extremely serious such as the infamous social exclusion which affects the pupils who frequent it, the mafias of drug dealers that hold the school in their claws and the serious lack of professional qualifications of the teaching staff.

"Geosciences" sought to foment the on-going training of teachers in secondary education strongly based on geoscientific topics, cultivating and stimulating the multiple possibilities of interdisciplinary work offered by the epistemology intrinsic to this field of knowledge, in a perspective in line with the Global Science Literacy. In order to make these affirmations more concrete, some examples of the activities of the participating teachers will be discussed below.

6. WORKING WITH GEOSCIENCES AND GLOBAL SCIENCE LITERACY IN BRAZILIAN PUBLIC SCHOOLS

With relation to Education in Geosciences, we can highlight some arguments that justify dedicating more attention to its teaching. From a strictly pedagogical point of view, the importance of the Geosciences is related to the very nature of its content, which implies the use and broadens the notion of space and time (as it deals with immense special and temporal scales), of relations of causality, of discussing and narrating histories and gives a more anthropocentric view of nature (Compiani, 1990, 1993, 1996b & c, 1998; Gonçalves 1989; Compiani & Paschoale 1990; Massa 1994; Brusi et al., 1994; Bezzi, 1995). The teaching of Geosciences allows pupils, to an almost exclusive degree in comparison with other sciences, to develop essential cognitive abilities and a spatial view as it involves local, regional and planetary dimensions of space (Kali, Orion & Mazor 1993) and their bi- and tri-dimensional representation. It is worthwhile quoting, besides those already mentioned above, the studies of Cuello (1988), Italia (1988), Brooks (1991), Alvarez et al. (1992) and Ault (1994) who emphasize that this area of knowledge fosters the development of multiple abilities and diversified ways of thinking in the pupils.

Moreover, the Geosciences have contributed a fundamental share in the History of Science: the knowledge that has caused great intellectual and cultural impact in our lives was the result of investigations that used historical and descriptive methodologies – e.g. the heliocentric solar system, the expansion of the universe, organic evolution, geological time or global climatic changes (Mayer 1991).

The above-mentioned features need to be dealt with systematically in basic elementary and secondary education. In secondary education, some crucial questions for the cognitive development of the pupils need to start being answered. The Geosciences have a major role to play in order to face the aspects pointed out by Pozo et al. (1991). The pupils must be introduced to the exercise of the causes and effects, both temporal and spatial, that are most distant from their daily lives; to exercise the explanation of phenomena with diverse causes in such a way as to begin building more complex reasoning, different from simple, linear causality. One of the steps is to work with the gigantic spatial and temporal scales and the indirect observation of various of the natural phenomena dealt with by the Geosciences. To exercise another conception of experience based on the observation of nature and the sky with great emphasis on perception/abstraction, description and graphic expression--to foster the conception/practice of experience that brings to light different practical aspects of physics and chemistry. The period that spans the 5th to 8th grades in basic Education is crucial for the development of more complex reasoning.

Some of the important interrelations between Global Science and the Geosciences that are being tested by our project are as follows:

- the Earth needs to be treated as a unit of study given the practical and theoretical problems posed by the environmental crisis;
- the Geosciences, as natural sciences, differ from Physics and Chemistry in their conceptual structure, principles and scientific methodology. They are

of utmost importance when dealing with physical-chemical processes and inorganic and organic material on huge and diversified spatial and time scales, describing, formulating and explaining the history of the planet by means of historical reasoning. The historical sciences stand out for the decisive role of narrative logic in their explanations (Frodeman, 1995), as well as the decisive role of context;

- the Geosciences are historical sciences of nature (Potapova, 1968; Paschoale, 1989; Mayer, 1991; Frodeman, 1995) and for this reason, the historical discourse of geoscientists seeks to explain how a past event occurred on Earth through observable "marks" of the event, which we take to be evidence linked to the processes that took place. That is, we begin from products, from the effects of an event in order to find the causes. It is reasoning from the effect to the cause;
- the Geosciences have an important role to contribute in training the children in the "alphabetization in nature" because they can stimulate the development of such capacities as: intuition and the development of visual language, appreciation of shapes and aesthetics, reasoning and spatial representation, reasoning of causality and the narrative involved in the historical discourses of the Geosciences (Compiani, 1990 & 1996c).

The structure of schools in Brazilian secondary education from the 5th to the 8th grade has a very defined and organized curriculum, based on the contributions of each of the traditional scientific disciplines. In the project, we test other ways of organizing the school curriculum, moving from disciplinary towards interdisciplinary and from structuralizing concepts (Compiani & Gonçalves, 1996) which could provide a backbone to all curricular organization. We seek concepts from other Sciences that could also be dealt with in the field of Geosciences. At the present moment, there is an atmosphere that favors the more conceptual organization of the curriculum, thanks to the great emphasis given to transversal topics in the new *"Parâmetros Curriculares Nacionais"(PCNs)* – National Curricular Parameters – which are being implanted in Brazil.

In the partial and final reports in preparation, there is abundant material in which topics of Geosciences and Global Science Literacy are developed and integrated with the teaching of Portuguese, history, geography, science and mathematics in an attempt to develop procedures and languages that provide a bridge with the more everyday knowledge of the pupils. The idea was to bring into the classroom the geographical and cultural context in which the school is located. There is a marked school culture of transmitting information based on definitions and content which is out of context and which does not allow for relations between the subjects and the everyday world. The content of most of the didactic books is descriptive and far from the geographical and cultural context of the pupils, unconcerned with dealing with more complex levels of concepts and problems based on, and integrated with, the context of the school itself and the pupils.

Two of the experiences carried out by the "Geosciences" project will be described below in order to give more concrete examples of the discussions that we have been having in this text.

To begin, we will give details of the work developed by the teachers of Geography and Portuguese in the 7th grade class of 36 pupils who study at night in the *"Escola Estadual Dona Valentina S. de O. Figueiredo"*, which took as its starting point the reality of the surroundings of the school and its pupils. It is an attempt to foster interdisciplinary work to seek a sharper perception of the region in which the school and most of the pupils are to be found. The intention was to obtain consistent texts, in which the pupils could describe, narrate and argue at the same time, using facts that were relevant to their lives and to them. In other words, that they should express a position they have taken up, reflections with available data, intentional viewpoints. The intention was to show that a good approach, taking local issues as a starting point and moving towards what is more generál, since locality encompasses questions of global nature, and from these could be constructed a coming and going between local and global, particular and general, singular and historic.

The school is situated in the neighborhood of Jardim Yeda, on the outskirts of the city of Campinas, and its pupils are needy, both financially and emotionally. An initial questionnaire confirmed many facts that the teachers already supposed; pupils belonging to the lower middle class; a minority of them employed (in industry and in tertiary services); school is seen as a chance for social ascension; very few leisure options.

It was decided that one of the most delicate topics for the pupils should be touched upon: the neighborhood where they live, in order to attain the problems that should be dealt with: the problems of a disorganized occupation of the physical environment, giving rise to the terrible standard of living there, including the lack of proper sewage which meant that domestic waste was discharged directly into a nearby stream. When asked in the questionnaire about the existence of the stream, most replied that they knew nothing. Now, it is difficult to consider this fact as truthful because the teachers knew that they lived in the surrounding area, many of them close to the banks of the stream that cuts through the middle of the shantytown.

Using the topic "water, a vital natural resource" as the concept to articulate learning, a effort was made to focus on the stream located in the neighborhood, which is part of a constant problem in the lives of these students, making a link between the place and the region using general concepts. More specifically, in this case the place is the Vila União stream in the municipality of Campinas, the region is Campinas and the general concept is the process of industrialization and its environmental consequences. The intention was to show that this stream is related to the urban context of Campinas, which, in turn, is part of a wider universe: that of an industrialized region.

The first activity to be carried out was requested by the Geography teacher: to gather information that the students had of the past history of the neighborhood so as to be able to discuss its most recent transformations. They were asked to individually report their memories with respect to the transformations witnessed in the neighborhood where they lived. The most common transformations reported were the implanting and inhabiting of Vila União, a neighborhood next to the school that the pupils knew well as it had only recently begun to be occupied, and the building of a hypermarket. Out of the twenty-four texts, ten mentioned the stream in

question, pointing out as the main problems the filth and the lack of care by the inhabitants, who throw garbage and various other domestic items into it. For the students, of all the transformations that had taken place, the only one considered negative was the degradation of the stream:

> And the stream used to be clean and then started getting dirty.
> People throw garbage and dead animals into it and when it rains we can't stand the smell.

As the stream was the articulating center of the work and the number of pupils that mentioned it in their texts was small, the attention of the rest needed to be brought to that area of the neighborhood. So, the Geography teacher discussed these texts giving special emphasis to the question of the stream and the related problems. As the texts also pointed out the urbanization of the area and population growth, the Geography teacher introduced texts about the history of Campinas and the importance of the rivers, taking advantage of the situation to relate the increase in population, the need for better sewage and water treatment, the need for awareness-raising to conserve the stream and from this, establish links between the water cycle, urbanization and hydrographic basins.

In the Portuguese classes, these texts were re-written, in other words, at the same time that they were produced, they were also read and discussed by the pupils. This happened in stages. Firstly, the work was developed with the texts on the neighborhood memory, but later preceded to all the other texts. They were read and then organized so as to better express what the pupil was trying to say. Extracts from some texts were written on the blackboard and corrected together with the pupils. Afterwards the students read each other's texts. At this moment, each pupil was in the role of reader of his colleague's text, a text that is close to what he himself is capable of writing, and therefore able to detect possible mistakes and solutions to improve the structure of the texts. The idea was to teach by reading, reflecting and discussing their own texts, for in this way they can socialize knowledge that had not previously been systematized, but that would gradually be transformed into significations that could be used by them.

To give continuity to the studies, the class was divided into groups and each one was responsible for obtaining a deeper knowledge, through texts supplied by the teacher, for one of the following topics: water treatment; pollution of rivers and streams; increase in the demand for water; water cycle; subterranean water; hydrographic basin; the history of the neighborhood and the history of Campinas.

The next step was to carry out fieldwork in the area surrounding the stream, for which the pupils were kept in their groups, with a list of activities divided into two parts. In the first, the pupils had to make a description of what they saw and answer some questions, such as: can you see garbage in the stream? What kind of garbage? In your opinion, what leads people to throw garbage into the stream? The second part was composed of interviews with the inhabitants with a view to gathering the following data: how did the occupation of the land take place? How did people in the neighborhood get along with one another? What was the opinion of the inhabitants with regards the channeling of the stream? Why was the garbage and sewage being deposited directly into the stream?

Besides the written copy of the observations in the area, there were other activities, such as drawings, the above-mentioned interviews and photographs. Each

pupil had the option of photographing what most called his attention, since the photograph was an important register for the socialization of the fieldwork in the classroom, since it showed the degradation of the place visited and contrasted with the stories told by the older inhabitants in the interviews.

Back in the classroom and in possession of the material, the pupils set up a panel with the photographs taken and prepared a seminar, which was previously prepared and included a display of texts. The discussion about the neighborhoods – the one of the school and the one where their homes were – was instigated by these texts, in which the pupils began to relate the geo-scientific and environmental questions previously discussed to the local problem, making a synthesis from the information obtained in the fieldwork. They presented a narrative that as well as being successive, contained elements of causality between the causes and effects of the reported events. There are clear similarities with the discourse of the geoscientists and, also historians, who use successive-causal narrative, as can be seen below:

> In interviews with the inhabitants, **the following statement was made**: *"The houses (or plots of land) of the Jardim Santa Lucia neighborhood were not donated, they were all bought"*. **They raise a hypothesis**: *"But who ever would buy a house facing such a filthy, stinking stream?"* **They discuss this**: *"The truth of the matter is that the stream, that is, the water of the stream used to be clean, very clean according to the inhabitants"*. **They return to the event (the pollution of the stream)**: *"And it got dirtier with time"*. **They look for the causes**: *"It's the inhabitants' lack of awareness and with the City Hall's failure to help because the garbage collectors do not come along this street and the dump is a long way away"*.

In this research, the disciplines of Portuguese and Geography worked together in the exchange of information, penetrating each other's field of action so that the pupils might establish a relationship of meanings. These meanings provide qualitative leaps for them to understand the place where they live and to see themselves as modifying agents of their own reality, building concepts through the "fusion" between what they already knew about the neighborhood (through common knowledge) and what could be added to this (through systematized knowledge).

Another example we are going to deal with is with regard to a Science teacher of 37 pupils of the 5th grade of the *"Escola Estadual Moacyr Santos"* on the topic "water cycle"(Sugahara & Compiani, 1999). The work on the topic "water cycle" sought to integrate classroom experiences that could help in the physical processes of the water cycle and Pascal's principle with a series of mediating teaching strategies and resources to deal with spatiality, direct and indirect observations involved in the phenomena under study.

Using two previous ideas of the pupils as a starting point, that is, that water emerges from surface processes or from the depths of the substrate, a series of mediating teaching strategies and resources were employed that emphasized and tried to deal mainly with the spatiality involved in the phenomena under study. For example, the use of illustrative transparencies (block diagrams of the Visual Atlas "The Earth"(1996) representing the hydrological cycle (p.40) and the elements of a water system of underground waters (p.45) illustrating the water cycle on the surface and on the substrate.

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The following experiment was carried out with the aim of seeking an analogy for the understanding of water infiltration. A beaker of sand and a glass of water was given to each group of 5 pupils. They were asked to add the water to the beaker of sand and to observe the experience. To exemplify how this activity developed, we quote the dialogue that took place during the observation (All the quotations of the pupils are reproduced *verbatim)*:

1. -*"The water takes a long time to reach the bottom of the beaker"*;
2. – *"Ah! The smaller grains have sunk to the bottom of the beaker and the bigger ones stayed on top"*;
3. – *"Ah! Bubbles are coming out"*;
4. – *"Ah! I put a lot of water, that's why it's floating"*.

Based on the first and third phrases of the pupils, the teacher establishes the relation between the terms "pores" and "spaces", saying that between the grains, there really exist these spaces/pores that made the infiltration of the water possible:

Teacher: *"Why is it that the bubbles appear after the addition of the water to the sand?"*
Pupil: *"Because there was air...."*
Teacher: *"But where was the air?"*
Pupil: *"Ah! It was between the grains...."*
Teacher: *"You're saying that between the grains there was 'space' with air?"*
Pupil: *"Yes."*
Teacher: *"But why did the bubbles come out?"*
Pupil: *"Because the water took its place."*
Teacher: *"That means that the air and the water don't occupy the same space between the grains?"*

The fourth phrase allowed the concept of saturated zone and non-saturated zone to be constructed:

Teacher: *"Why is it that the water didn't infiltrate more?"*
Pupil: *"Because there is too much water and it met an obstacle that didn't allow it to infiltrate any more...."*

The pupil compared the glass side of the beaker to the impervious rock that didn't allow the water to infiltrate. The water that filled up the spaces between the grains was compared to the formation of the water table. The water on the surface, above the sand, was compared to the water of a lake. The first illustrative transparences were displayed again, showing the saturation zone and the non-saturation zone, the role of impervious rock for the formation of the ground water and the lake. With the use of the transparency, the pupils established a comparison of the water cycle with the process of water infiltration that gives rise to the elements of a system of subterranean water. Some of the processes of infiltration are observed directly, for others this is not possible. The pupils see the water infiltrate in the soil, but they do not see the soil becoming saturated and the water forming the water table--hence the need for the experiment in the laboratory and the visual resource to 'model' the processes of indirect observation.

Immediately following this, with the aim of discussing the understanding of the formation process of the saturated zone and, consequently, the process of formation of a lake or river, an exercise was proposed to the pupils consisting of the

following question: "What would happen if it rained heavily for several days in the different types of relief?" (Two types of relief, one flat, the other irregular were drawn on the blackboard). Most of the pupils replied that it would soak the flat land, forming puddles. The transparencies previously worked on made these answers easier. The answer to the irregular relief was given more warily, more timidly. It seems that the questioning left many of the pupils perplexed in the face of what in fact happened. In contrast, one pupil stated that

part of the water would flow off the surface and the rest would infiltrate. When the water found an obstacle (a rock, for example), it would be deposited in the spaces between the pores until it reached saturation point, in such a way that it would emerge at another point, forming sources.

Another pupil associated the process of forming sources with Pascal's principle. In the class on water pressure, the teacher worked on the concept using a previously punctured balloon and tap water. The pupil said

when the water infiltrates, it finds a rock and goes on depositing until it reaches a level of saturation. Then it is forced to emerge at the lowest point of the land. The rain can be compared to the tap water which was infiltrating and, when it filled part of the balloon, the water came out of the holes existing in the lowest part of the balloon

The pupil associated the principle that had been shown and experimented in the classroom to the process of forming sources.

As part of the activities, one more exercise was proposed: the pupils should draw a reservoir of subterranean water. Below can be seen just two of the pupils' drawings:

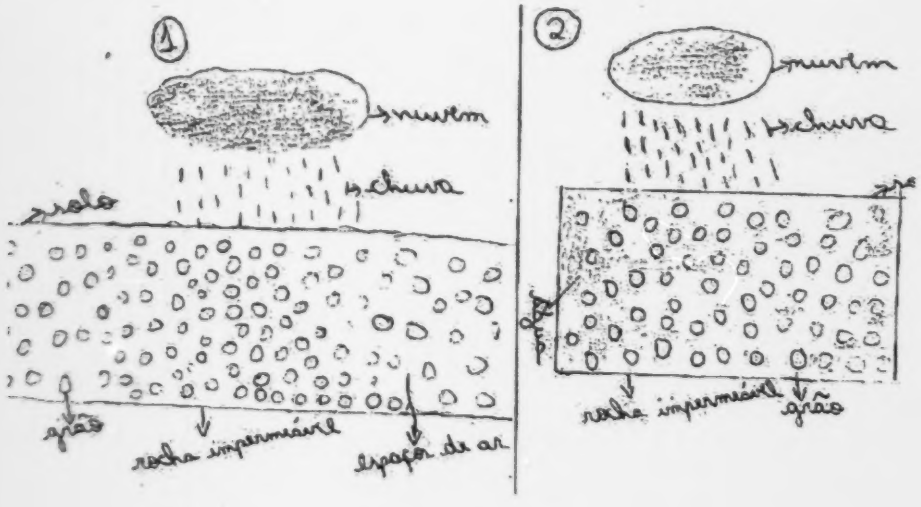

Figure 1. Student representation.

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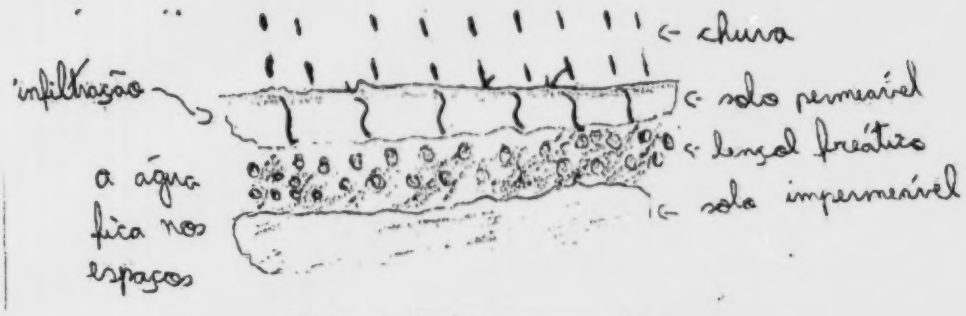

Figure 2. Student representation.

The figures are quite different as representations. In figure 1, the pupil used the illustrations and captions made by the teacher to exemplify the pores of the substrate as a basis for his drawing. Figure 2, however, was a 'creation' of the pupil, since the teacher had drawn nothing like it on the blackboard. In both figures, the pupils are not far from what would be the closest representation to the scientific structure. Figure 1 is a more formal and Figure 2 more illustrative ('copying what is real'). In some way, the pupils integrated the images and concepts worked on in class, and, besides this, managed to reproduce them. The pupils managed to reproduce and integrate important concepts such as water infiltration, the imperviousness of the surface to block this infiltration, the porosity to 'stock' water, the zone saturated with subterranean water and the non-saturated zone. Equally important is the representation of precipitation as a source of water for infiltration and part of the water cycle.

Considerable work was done on spatial reasoning and visible and not visible phenomena. For example, the experiments with Pascal's principle were carried out in an integrated way so as to provide information for the understanding of the water cycle. We need to carry out a more systematized evaluation but we believe that we are modifying the habitual rules of the everyday causal reasoning of the pupils that, according to the studies of Pozo et al. (1991), is the spatial and temporal contiguity between cause and effect. The cause must be spatially close, if not in direct contact with the effect, and there is a tendency to seek the causes of facts in the phenomena immediately prior to the effects. These studies also point out the difficulty of pupils to use multiple causal explanations, perhaps because correlational reasoning is one of the least developed, not only in adolescents but also in adult university students.

7. FINAL CONSIDERATIONS

The experiences reported above sought to involve topics of Geography, Portuguese and History, dealing with time integrated with the concept of space and paying special attention to locality. Landscape makes geographical space particular and gives it a context as it integrates individual, family and social histories. Individual and social narratives integrate with geographical and geological narratives. One idea

is to start building a methodology for the teaching-learning of the structuring concept of time, integrating the natural processes of the Earth's movements with chronological, social and historical time, and also with archeological and geological time.

Other activities are an example of what we can develop in the disciplines of Science and Geography, in which special attention is given to topics that deal with a variety of processes on different scales of time and space, as well as with a diversity of relations of cause and effect, from the linear to the multiple causal explanations. The adoption of topics that work with analogies, spatial-temporal patterns, models, successive-causal narratives and historical argumentation is also encóuraged.

It is fundamental for the teaching of Global Science, Sciences and Geosciences to work with natural processes on different scales of time and space. In the project, there were a variety of schools in diversified urban spaces, which was a great incentive for the fieldwork that made the observation/interpretation and the representation of nature possible. These studies of nature are intrinsically linked and provide a basis for the work with the geographical categories of place, landscape, and territory as well as with the formulation of analogies and models of natural processes from observations and fieldwork, so important in Science teaching.

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CHAPTER 16: USING PROBLEM-BASED LEARNING TO STRUCTURE ONLINE TEACHER PROFESSIONAL DEVELOPMENT

Robert J. Myers, Wheeling Jesuit University, USA

1. INTRODUCTION

A growing body of science educators states that students should learn science as a process and should engage in meaningful, relevant tasks that allow them to interpret their world in scientific terms (Tobin, Tippins, Gallard, 1994). To prepare teachers for this challenge, the National Science Education Standards (NSES) (NRC, 1996) call for professional development similar to that of other professions. That means that because the knowledge base continues to expand, science teachers must make a career-long commitment to stay up to date and proficient.

The NSES reform effort also requires a substantive change in how science is taught. Too often professional development emphasizes traditional lectures and the usual technical approach to teaching. The NSES suggests a different plan: "Professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability" (p. 56). Perhaps most significant, the standards propose that "prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding" (p. 60). The concept is simple: If you're going to teach to the standards, you first had better experience them and their vision of science yourself.

The standards call for students—alone and in groups—to actively engage in scientific inquiry to develop understanding about the natural world. Students are to conduct inquiry into authentic questions generated from experiences. This requires students to pose questions about scientific phenomena; develop plans for investigation; gather, analyze, and interpret data; and present findings or recommendations.

To help teachers thrive in this environment, the standards state that college faculty must develop courses based on investigations. Teachers use technology to gather and interpret data in these investigations. They also collaborate on authentic, open-ended problems. This collaboration lets teachers experience inquiry methods along with inquiry's rewards and challenges.

Teachers involved in inquiry play a leading role in the professional development described in this chapter.

2. TEACHER PROFESSIONAL DEVELOPMENT

Loucks-Horsley, Hewson, Love, and Stiles (1998) in their book, *Designing Professional Development for Teachers of Science and Mathematics*, state that the principles guiding reform for students' learning should also guide teacher professional development. They remind us that teachers teach as they are taught, so engaging them in "active learning, focusing on fewer ideas more deeply, and learning collaboratively are all principles that must characterize learning

opportunities for adults" (p. xix). Their model includes individual teacher reflection, a focus on learning or improvement, mechanisms for feedback and sharing, and opportunities for interaction. They also recommend a climate of trust and collegiality, a long-term commitment to interaction, and skill building in coaching and mentoring.

3. PROBLEM-BASED LEARNING

We looked to problem-based learning (PBL) as the method to provide an inquiry-based environment. PBL facilitates active student participation, fosters problem solving and metacognition, enhances self-assessment, and increases students' ability to access and use information (Dunlap, 1997; Seifert, 1997). Through its constructivist orientation to teaching and learning, PBL meets all of the criteria laid out above for inquiry-based science classrooms. Finkle and Torp (1995) state,

> problem-based learning is a curriculum development and instructional system that simultaneously develops both problem-solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem solvers confronted with an ill-structured problem that mirrors real-world problems (p. 1).

The online graduate course we developed supports Finkle and Torp's vision. It immerses teacher-participants in real-world problems—problems that allow them to master critical thinking skills while learning environmental and Earth system science (ESS) content.

Brooks and Brooks (1993) state that learners of all ages are more engaged in problems addressed in "whole to part" forms. This structure allows for multiple-entry points and addresses multiple learning styles. Providing an overarching problem set also creates a purpose for engagement instead of the usual assignment of a chapter and end-of-chapter study questions. Students know from the outset where they are headed and why.

PBL confronts students with an ill-structured problem that lets them find personal relevance. Barrows (1988) defines ill-structured problems as follows: a) more information than is initially available is needed to understand the problem, b) the problem definition changes as new information is added to the situation, c) many perspectives can be used to interpret information, and d) no absolutely "right" answer exists. Well-structured problems—the kind students traditionally face—provide students with all necessary information, including the appropriate algorithms to arrive at a single correct answer. Student motivation to solve the problem revolves around finding the answer the teacher desires. This is likely to lead to inert, unusable knowledge. When students work to solve ill-structured problems, they are learning generalized procedures for problem solving that will transfer to new situations (Simon, 1980; cited in Frederiksen, 1984). PBL also creates an active learning environment in which students pose the questions they will address in order to solve the problem. This process provides for ownership of learning and increased student engagement and motivation (Barrows, 1996).

4. THE HIGH SCHOOL TEACHERS' ESS

NASA and other research institutions study Earth's changes as a system (USRA, 2002). In 1997 the Center for Educational Technologies® (CET) at Wheeling (WV) Jesuit University, with support from NASA's Earth Science Enterprise, began developing online graduate courses for teacher professional development. The guidance to the CET was straightforward—address teachers' lack of Earth system science knowledge. The challenge became designing courses that would require teachers to experience inquiry in the same way their students would. The professional development courses would feature knowledge-building communities in which teachers work cooperatively to learn Earth system science.

The high school course was designed to model PBL and its support of the National Science Education Standards. PBL provides a constructive, supportive, inquiry based environment for teachers to learn about Earth system science. Teachers can then use that approach to engage their own students.

4.1. The learning environment

The high school course is delivered completely online through the Internet. The web site includes background information, grading rubrics, a syllabus, and a threaded discussion area. No face-to-face meetings are held; the entire course is conducted in a structured, asynchronous mode. That means each week teachers are expected to accomplish specific tasks. Participants determine when they go online to complete the requirements.

The 16-week, three-credit hour course is divided into an introductory section of three weeks and four 3-week modules (see Figure 1). The long introductory section allows for a leveling of skills in computer usage, web knowledge, ability to operate in threaded discussion space, and Earth system science modeling. Our prior experience with online courses suggested that many teachers lack the requisite skills or background to immediately launch into collaborative problem-solving activities (Davis and Myers, 1998). In accordance with Loucks-Horsley, Hewson, Love, and Stiles (1998), we designed spaces for reflection, feedback, sharing and opportunities for interaction. The 16-week duration provides for a longer-term commitment to interaction and knowledge building.

During the first three weeks the course facilitator assigns teachers to groups of four to six members. Because of the rigor of the course and the intensity of effort, each course can have only 20 to 24 participants, usually divided into four groups. In addition, teachers receive a demonstration problem and assistance in moving through the PBL process. For example, teachers read about Earth system interaction analysis and form causal chains based on a volcanic eruption.

Four modules follow the introductory period. In these three-week-long modules teachers problem solve, build models, and design learning experiences. The modules cover coral reefs, deforestation, ozone depletion, and global climate change.

Week by Week	
Orientation	
Week 1	**Individual:** Read the Intro. Read the Guide. Read about Earth system science. Do the Pre-Course Survey. **Team:** Meet and name your team.
Week 2	**Individual:** Read about the PBL Model and how it can be integrated with the ESS analysis. Practice PBL and ESS with the Volcano Scenario. **Team:** Work with your teammates on the Volcano Scenario.
Week 3	**Individual:** Read about hypotheses, ESS analyses, questions, and problem statements. **Team:** Examine and make suggestions for the PBL Design Rubric criteria.
Coral Reefs	
Week 4 Teacher as Problem Solver	**Individual:** Private Theory—List your private theories. **Team:** Knowledge-Building—Ask and answer questions; write a problem statement.
Week 5 Teacher as Model Builder	**Team:**
Week 6 Teacher as Designer	**Individual:** PBL Lesson Design--Design a PBL lesson; act as a critical friend to two teammates; reflect on your learning.
Tropical Forests	
Week 7	**Individual:** Private Theory—List your private theories.

Figure 1. Course outline

For simplicity the design team divided each of the four-week modules as follows:

- Week A: Teacher as Problem Solver
- Week B: Teacher as Researcher
- Week C: Teacher as Designer

4.2. Week A: Teacher as Problem Solver

As problem solvers, teachers read a scenario depicting an authentic Earth system science problem. For example, the coral reefs module begins by depicting the distress that coral reefs worldwide are experiencing. The information cites the Environmental Protection Agency's statement that Florida's coral reefs experienced a 292 percent increase in disease between 1996 and 1997 (MacLaughlin, 2002).

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Teacher-participants play the role of Earth system scientists. They are asked for a thorough evaluation of all the factors affecting coral reef survival.

Week A: Teacher as Problem Solver is divided into two sections. First, as soon as the scenario is read, participants are asked to write down what they know about the topic. This requirement comes from the familiar KWH chart used in PBL[1]. Each participant lists what is already known about the topic, in this case, coral reefs. We label this information the private theory submission. Teachers have a rubric to guide their thinking (see Figure 2).

Listing private theories already held by each individual provides a baseline of knowledge and allows learners to identify closely held beliefs that lead to misconceptions. After the private theories are listed, individuals then meet with their group in another discussion space to consolidate what is already known and to develop a list of questions for further investigation. (Later, in Week C participants reflect on what they know after completing the module. We call this the reflective theory submission.)

Belief: What you really believe to be true. "I think..."			
4 Rating: A clear summary and powerful questions about the event and the Earth's systems.	**3 Rating:** A summary statement of what you think, and some follow up questions.	**2 Rating:** A description of ideas you have.	**1 Rating:** A list of some ideas.
Reasons: Supported by reasons. "Because..."			
4 Rating: Your thinking is visible with clear ESS explanations or assertions in support of your hypothesis.	**3 Rating:** Your hypothesis is supported with some ESS explanations or assertions.	**2 Rating:** Some reasoning behind what you believed is revealed.	**1 Rating:** Some reasons given for how you know what you think you know.
Source: Uses what you currently know. "These reasons come from..."			
4 Rating: Relevant knowledge and reasons from multiple sources and examples from your experience.	**3 Rating:** Relevant knowledge and reasons from a few sources and/or relationship to experience.	**2 Rating:** Relevant knowledge is supported by at least one reason or some relationship to experience.	**1 Rating:** Some related experiences and references or schooling is given.

Figure 2. Private theory rubric

4.3. Week B: Teacher as Model Builder

[1] In KWH, learners list what they **K**now about the problem, next they ask **W**hat questions they need to answer in order to address the problem, and finally they address **H**ow they are going to learn what they need to know.

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During Week B: Teacher as Model Builder, the groups craft a problem statement. Then they begin their investigations to answer their questions. They use the Earth system diagram (see Figure 3) to support and extend their thinking. Participants also use the Internet and appropriate NASA-related materials mailed to them at the beginning of the course. While they are given some appropriate URLs to get them started, participants are expected to access the Internet, available library resources, and other appropriate resources. In some cases only the Internet is available to them, but, of course, its scope is extensive. The important point is that this is a knowledge-building community: Participants uncover material instead of listening to lectures or reading a specific chapter required by the instructor.

The course instructor becomes a mentor and facilitator. This role is so important in a student-centered environment. The instructor can help participants by setting expectations, moving out of the middle and coaching from the side, so to speak. Posing guiding and redirecting questions becomes an art. Getting misguided groups back on track becomes challenging when one wants to avoid being overly directive, yet wants the participants to make the most of available time.

Having participants think critically at this juncture is one of the main thrusts of the course. Each time individuals make an assertion; we expect support from personal research, logic, or appeals to higher authorities, e.g., research articles

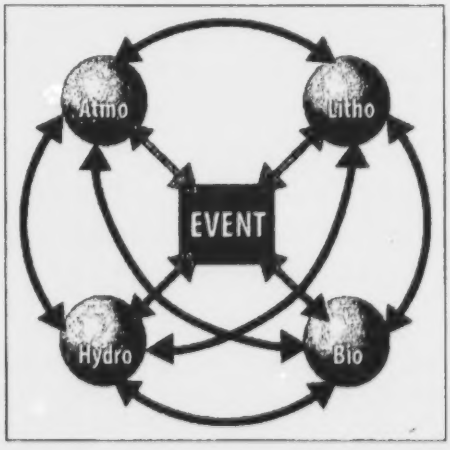

Figure 3. Earth system diagram

or interviews with experts. We also expect participants to recognize questionable or spurious support and to select credible sources within the scientific community. Participants should take back these same expectations to their classrooms. For example, in discussing the 1988 Yellowstone fires and in looking at the fire's impact on the atmosphere, the participant might write, "The forest fires could cause acid rain." Then he or she gives a reason: "As with industrial pollution, CO_2 from the fire would combine with the moisture in the atmosphere to form carbonic acid, or H_2CO_3." The reason is followed by the source(s). Such explanations display an

understanding of the science behind the interactions. These explanations are valuable in making the "why" or "how" visible.

Often new information provides more questions to answer. However, as Week B winds down, the groups analyze their data, synthesize their thinking into an Earth system diagram, and compose recommendations based on their analysis.

4.4. Week C: Teacher as Designer

Too often teacher-participants attend an in-service or take a course but do not transfer new knowledge or skills to their classrooms. During Week C: Teacher as Designer, participants design a PBL lesson for their own classroom using the subject matter and methods they learned during the first two weeks. First they identify connections to their own curricula by listing learning objectives. They also link to national, state, or local standards. And they consider concepts and skills that need to be addressed. Then they write a new or adapted PBL scenario to support their students' developmental levels.

As noted previously, at the end of Week C, participants revisit what they have learned. This is called the reflective theory submission. By looking back at their initial submission, they see their growth in knowledge from a metacognitive sense. This step also asks them to provide sources that have modified or added to their knowledge base. They also must support any new assertions with evidence. The reflective theory submission introduces rigor in the participants' thinking—a practice that will be valuable to them with their own students.

The teachers also act as critical friends in Week C. They provide feedback to each other after the scenarios are posted in the discussion space. The critical friend reads for understanding, asks clarifying questions for understanding, and summarizes the lesson. This reviewer also reads for power to ensure the lesson confronts students and engages them in exploiting new information and ideas.

5. THE STUDY

The major goal was for teacher-participants to increase their content knowledge of Earth system science. To measure this growth, we expected that participants would be able to create Earth system diagrams showing causal chains. Within the chains would be assertions or statements of fact about an event (e.g., volcanic eruption or hurricane) and the impact on the spheres through positive and negative feedback loops. The evidence or reasons for participant's assertions would be based on personal experience, logic, or appeal to higher authority. This study analyzed both the number of assertions and the supporting reasons teachers made during their Week A private theory submission and their Week C reflective theory submission. We expected to see a significant increase in both assertions and supporting reasons from Week A to Week C.

5.1. Method

Participants. Volunteering to take the beta course were 13 teachers from across the country. They were awarded three graduate credit hours for participating. Participants taught various forms of science (See Table 1). Of the 13, 10 completed the course.

Table 1. Participants

Teacher	Number of Years Taught	Level	Subjects	School Demographics
RB	26	9	Earth science	Suburban
CB	3	9,10,11-12	Earth science	Urban
CD	3	Veterinarian		Suburban
DL	12	9,10, 11-12	Chem, Physics	Suburban
DM	5	9,10	Bio 1, Chem 1	Rural
BP	10	11,12	Env Tech1,2	Rural
RQ	1	9,10	Earth Science	Suburban
AS	10	10,11,12	Earth Sci, AP Chem	Suburban
MS	20	9,10,11-12	Chem, Physics	Urban
JZ	5	9,10,11,12	Integrated Sci	Suburban
MA	14	9	Tech, Earth Sci	Urban

Data Scoring. Three Earth system science professors not connected with the program were selected to score participants' submissions. Interrater reliability was established through a practice session in scoring submissions from another section of the online high school ESS course. Raters counted the occurrences of Earth system assertions or statements and the number of supporting reasons or evidence for both Week A and Week C.

Results. A 2X4 mixed group analysis of variance was performed on the number of assertions and the number of supporting reasons made by individual participants. Results indicate that the main effect of time of submission was significant, with the subsequent testing resulting in greater performance for the dependent measures ($F(1,63)=18.582$, $p<.0001$), ($F1,62)=19.678j$, $p<.0001$) respectively. Furthermore, the main effect for the module ($F(3,63)+3.002$, $p=.037$) was significant for the number of supporting reasons that were given by the students. Analysis of the main comparisons on the effect of module yielded significance indicating the global change module resulted in greater number of supporting reasons as compared to the coral reef and the deforestation modules. Table 2 shows how the number of assertions and the number of supporting reasons vary as a function of time the module was taken and the module that was studied.

Table 2. Number of assertions and number of supporting reasons as a function of time the test was taken and the module that was studied

		Number of Assertions		Number of Supporting Reasons	
		Private Theory	Reflective Learning	Private Theory	Reflective Learning
Coral Reef	Mean	15.25	27.8	11.85	20.48
	SD	5.82	9.31	4.23	8.16
Deforestation	Mean	17.73	25.5	15.53	25.92
	SD	5.84	9.8	4.52	15.24
Ozone	Mean	15.38	20.33	12.83	19.92
	SD	6.86	8.72	5.44	8.28
Global Change	Mean	15.67	23.42	18.1	29.1
	SD	7.6	10.26	7.83	14.42

5.2. Discussion

This course was designed to support learners' successful use of PBL to learn Earth system science in an online environment. Based on the authors' experiences with PBL in face-to-face situations and prior experience with collaborative structures online, the timing, resources, and spaces within the course were designed to support maximum engagement with PBL associated with strong content knowledge gains.

If PBL were a viable instructional tool for online learning of complex content, we would expect it to reveal and affect learners' private theories. The study supports the notion that participants' private theories do evolve, increasing with elaboration over time. While it is reassuring to see these gains, the whole PBL process is based around forming questions and seeking answers. This is where the knowledge gains come from. And so we expect the process to cause learners to generate questions that are worthy of and interesting to answer. We would expect learners to actively and successfully find answers to those questions and that this process would increase learners' Earth system science knowledge. It was particularly noteworthy to see that the last module, global climate change, had significantly more assertions and reasons. That suggests that as the course progressed, participants were becoming more attuned to making their thinking visible.

The statement of private theories fueled the generation of questions. When team members shared their questions, they found overlap as well as unique questions. As one person put it, "My questions seem to be more abstract because I know less than the other team members, but I really think all the questions are cool."

They posed fact-finding, theory-building, and higher-level thinking questions. This suggests that learners were engaged early on in thinking about the situation in terms of interaction and relationships. Participants helped each other to answer questions as well as to pursue answers to their own questions.

The interplay of ideas and opportunities to reexamine one's own ideas seemed to provoke ongoing research and formulation of explanations within the ESS framework. Said one participant, "Working with the ESS diagram and with the other teachers has helped me organize many of the facts and theories I already had."

In addition to the data analyzed, all participants reported in a course survey that they developed their content knowledge: for example, "Yes. I learned a lot about the connections between Earth science systems, the PBL method of learning, some current environmental problems."

Many reported having used PBL with students before the end of the course: "I have tried one of the PBL lessons I developed for this course with my students. They responded better than I expected. As a result I find myself increasing my expectations."

All felt confident in using the PBL process and expected to raise their expectations for student outcomes: "I expect the students to be able to think for themselves more. I have tried to incorporate activities to allow students to express their personal ideas, but I have noticed that it is so ingrained in them to rely directly on books and the teacher that they really struggle with this. I do want to continue to expose them to these types of activities so that maybe some of them can realize their capabilities and knowledge."

This sentiment is an indirect indicator of teachers' own increased confidence with the subject matter and PBL and the teachers' sense that it results in strong outcomes. One person reported, "I am very glad I was able to take this course and feel I have profited greatly from it. I have been asked to put together a presentation about either PBL units. I will be sharing a lot of what I have learned and experienced with the entire science department here."

6. CONCLUSIONS

The success of this course in achieving its increase in content knowledge suggests that PBL can serve as an online professional development tool. Some important course design features might have contributed to the successful use of PBL in this online environment.

Although these results suggest that PBL is a viable professional development tool for content knowledge development, the degree to which the design of the site and the course affected learning outcomes needs to be examined further. What were design features that supported the successful use of PBL in the online environment? How was PBL altered in this environment, if at all? Timing, expectations, discussion spaces, the interplay of individual and team activities—all seemed to have a bearing on learner engagement.

In problem-based learning, learners make their thinking visible, from revealing private theories to formulating hypotheses and problem statements, from doing research to building explanations. The online environment can be structured to take full advantage of this tool to create a successful knowledge-building environment.

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CHAPTER 17: PREPARING TEACHERS FOR SYSTEMS SCIENCE METHODOLOGY

Kim, Chan-Jong, Chongju National University of Education, KOREA

1. INTRODUCTION

Stereotyped methods of science originating from the physical sciences have been dominating school science. Mayer and Kumano (2002) discussed the problems in detail. They insisted that science methods different from those in the physical sciences are dominant in Earth systems science. Mayer and Kumano (2002) adopting Lazlow's term called this 'systems science methodology'. In systems science methodology, observations and interpretations based on earlier conceptions, rather than controlled experiments, are known to play major roles.

Others have suggested similar ideas. A German philosopher, Engelhardt, and a German geologist, Zimmermann (Engelhardt and Zimmermann, 1982), collaborated to analyze the Earth science reasoning methods and suggested abductive inference as a major form of reasoning in Earth science. Abduction, first introduced by the American philosopher, Peirce, in the late 19th century, has been regarded as a promising tool to understand human reasoning and knowledge development in many disciplines. Abductions are sometimes called IBE (inferences to the best explanation) by philosophers (Ladyman et al., 1997), and are the type of inference in which one derives the conclusion that best explains the available evidence.

Abduction attracts many philosophers today as a mode of reasoning underlying almost all current defenses of scientific realism (Ladyman et al., 1997) and everyday thinking (Josephson & Josephson, 1996). Much debate has continued around this topic recently (Fraassen, 1989; Ladyman, et al., 1997; Psillos, 1996; Richmond, 1999) in the area of philosophy. Abduction has also attracted many specialists in the fields of artificial intelligence (Josephson & Josephson, 1996) and educational technology (Shank, et al., 1994). Many researchers in these areas believe that abduction can and should play an important role in instructional design and delivery. These researchers have been developing and improving computer programs using abductive inference.

Abductive reasoning could contribute to the elaboration of systems science methodology, and provide a more solid foundation to establish more effective instructional strategies for systems science. In this chapter, abductive inference will be discussed in relation to systems science, and instructional strategies for teacher education based on abduction will be introduced.

2. SYSTEMS SCIENCE METHODOLOGY AND ABDUCTION

Methods are often closely related to the goals and objects of inquiry. Laudan (1987) clarified the goals of geological science research, and divided them into two groups, causal and historical. In this section, causal and historical inquiries will be clarified, and then the major reasoning methods employed in each inquiry will be explored. Laudan (1987) explained causal and historical inquiry as follows.

> A scientist who seeks to develop a causal theory aims to establish general laws connecting causes and effects (p. 4). ... In causal theories, the crucial entities are "natural kinds" - that is, classes of objects with some nontrivial property or set of properties in common (their essences). They are distinct, timeless, and immutable. As an example, consider the geological kind "basalt." Every instance of basalt will have a common property-namely, a common chemomineralogical composition (p. 6).
>
> For the historical geologist, the time sequence is paramount. As usually construed, the historical geologist aims to reconstruct a sequence of unique events (p. 5). ...In historical reconstructions, the crucial entities of historical inquiry are unique historical events or more precisely, the rocks that were formed during a particular time period. Werner defined a "formation" as the collection of rocks formed during a certain period. Each formation is unique because it is limited to a particular period of time, quite unlike a natural kind (p. 6).

Laudan's explanations of the goals of geological science are summarized in Table 1. Causal and historical researches show very different aspects in terms of objectives, entities, and results. The distinction between historical and causal inquiries could provide crucial guidelines in understanding the nature and methods of systems science. According to Laudan (1987), causal research has historically adopted various methods, including induction, analogy, controlled experiments, and so forth. The dominant methods used by geologists in each goal of inquiry need to be explored.

Table 1. Comparison of causal and historical research in Earth systems science

Goals of inquiry	Causal	Historical
Objectives	Establish general laws Connect causes and effects	Reconstruct a sequence of unique events
Entities	Natural kinds	Formation
Results	Laws or principles of Earth science	Chronicles

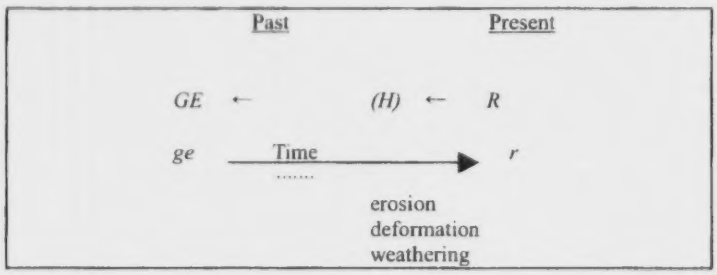
2.1. Dominant method in historical inquiry

Engelhardt & Zimmermann (1982) argued that most topics in Earth history could only be studied abductively, since they involve events that are long past (p. 210). The events of the geologic past, the origin of the oceans and continents, and the course of Earth's development are some examples.

Consider what geologists do to reconstruct the geologic past. Typically geologists explore the outcrops of a field area and describe the region in terms of formations, rocks, fossils, geological structures, and so on. They also conduct laboratory work with samples collected in the field, using microscopes, chemical

analysis or physical investigations. They then infer about the past events based on their findings. These processes are diagrammatically illustrated in Fig. 1. Assume that a geological event, *ge*, occurred in Earth's history. Only some partial evidence, *r*, is left at present, because erosion, deformation, or weathering destroyed or erased some of the information about the geologic event in the geologic strata. Geologists investigate *r* and describe it (*R*). They examine scientific principles or hypotheses and select the best hypothesis (H). They reconstruct geologic events with the hypothesis selected and explain what occurred in the area in the past (Fig. 1).

For example, if geologists investigate a region (*r*), and in their description an unconformity is cut by a set of faults (*R*) their interpretation is that the unconformity precedes the faults. The history of this region consists of deposition of layers, uplift, and sinking for a second stage of sedimentation. Subsequently, for some reason, faulting has occurred. In historical research, geologists usually have parts of the evidence. With the evidence remaining, they can reconstruct the geologic past. To do this, they cannot help to adopt abduction.



ge: geologic event, *r*: remnants of the past event, *R*: proposition describing r, *H*: hypothesis explaining underlying relationship

Fig. 1. Process of inference in historical inquiry

2.2. Dominant methods in causal inquiry

The reasoning adopted in a typical historical inquiry was explained in the previous section. In causal inquiry, the goals are quite different from historical ones. Scientists attempt to establish general laws connecting causes and effects, as in other disciplines such as the physical sciences. However, the special characteristics of the objects to be investigated have a strong influence on the methods of Earth systems science. Some researchers have suggested the special problems geologists frequently face. For example, Laudan (1987) pointed out that the inaccessibility of many geological processes, the relevance of experimental evidence, the long time period required for many geological changes, and the complexity of geological phenomena are the special problems geologists frequently face. One of the most crucial problems for geologists is inaccessibility. Engelhardt and Zimmermann (1982) also pointed out non-observable conditions as major problems for geologists. For example, the deep zones of the Earth's body are inaccessible. Therefore the structure of the Earth's body cannot be inferred from induction or controlled experiments but

must be inferred abductively (p. 210).

Other characteristics, such as the complexity of geological phenomena and the difficulty of separating and manipulating variables, make geologists unable to depend on the experimental method. Laudan (1987) explicated this with an example. The transformation of a region from ocean into continental land might well be considered as a single event, but it could only be explained as an overwhelmingly complicated effect produced by an intricate sequence of operations conditioned at every stage by the cooperation of a whole battery of natural agencies (p. 10). Many themes in Earth science, such as global climate change, sea-level change, plate movement, or continental uplift also show similar properties. Therefore, geologists usually rely on descriptive or interpretive methods rather than experimental ones.

2.3. Abduction and systems science methodology

In this section abductive inference is explained with examples and compared to systems science methodology. Abduction is a form of inference that goes from data describing something to a hypothesis that best explains or accounts for the data. Therefore abductive inference is theory generating or interpretive inference, or a hermeneutic method (Frodeman, 1997). Josephson & Josephson (1996) explained the logic of abductive inferences as follows.

> D is a collection of data
> H explains D (would, if true, explain D).
> No other hypotheses can explain D as well as H does.
> ---
> Therefore, H is probably true.

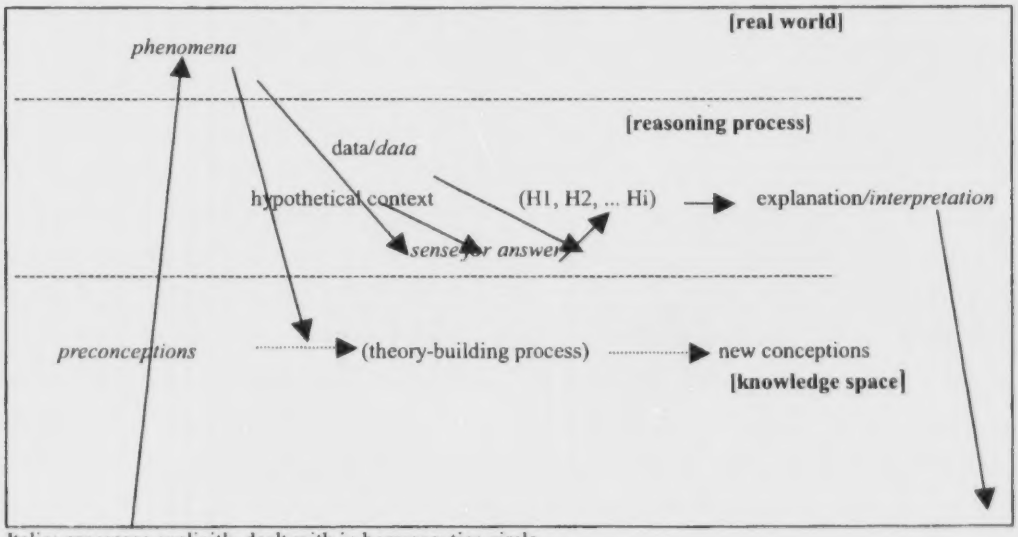
As we can see from the logic, abduction is incomplete inference. However, abductive inference becomes more certain when, instead of many alternative hypotheses, only a few, more probable ones are actually considered, some of which can moreover even be weighted as being either more or less plausible (Engelhardt & Zimmermann, 1982). To eliminate less probable hypotheses, or to give weight to plausible hypotheses geologists should have some information on the possible conditions of the phenomena. In this sense, abduction involves a search for hypothetical conditions that are linked with suitable laws to describe the data exactly. Engelhardt and Zimmerman (1982) clearly showed an example of this as follows.

> Given, for instance, a stratum of sand (e) observed in nature, whose bedding position, structure, grain size distribution, etc, are all known. To explain this phenomenon we must first decide whether the hypothetical context from which we are to derive the formational conditions (a) of the sand, should be deposition through flowing water, or deposition by wind. Each of the two hypotheses is represented by a physical model implying the special laws, namely the law of transport of sand grains in water, L_W, or transport in air, L_A. Having chosen one or the other hypothesis, laws L_W or L_A may be applied, and from them we infer the causally effective conditions a_W or a_A in water or sand, in which may have led to the deposition of this particular stratum of sand (e) with its special features (p. 211).

Abductive inference could be summarized as consisting of data, hypothetical

context, and explanations. It is very similar to the systems science methodology, i.e., Frodman's hermeneutics circle (1997): data, preconceptions, foresight, procedures, and interpretations. To understand the roles or relationships among the components of both reasoning methods, a diagram has been developed (Fig. 2). Although the hermeneutics circle describes the grand aspects of the reasoning process, it cannot provide sufficient explanation of the reasoning process in detail. On the other hand, abduction focuses only on the reasoning process itself rather than the overall aspects of inquiry. Therefore, to combine both, we may have a more complete picture of systems science methodology.

Geologists collect data on some phenomena based on preconceptions. They also examine hypothetical conditions in the same situation. Our sense of what will count as an answer is deduced from the hypothetical conditions and preconceptions. Foresight, the presumed goal of our inquiry and our sense of what will count as an answer will serve to select the best hypothesis from among alternative hypotheses or eliminate unsuitable ones. According to the selected, best hypothesis, explanations or interpretations will be established (Fig 2).



Italic: processes explicitly dealt with in hermeneutics circle
Normal: processes explicitly expressed in abductive inference

Fig. 2. The abductive/hermeneutics process

3. TEACHER PREPARATIONS AND SYSTEMS SCIENCE METHODOLOGY

To prepare science teachers for systems science methodology, at least two provisions must be satisfied. First of all, pre-service teachers learn Earth systems science according to systems science methodology. Second, they have to understand and be able to apply instructional approaches based on systems science methodology.

3.1. Systems science method and teacher preparation of the content

Learning systems science through systems science methodology has two implications. First of all, this might be an effective way of learning Earth systems science. Many topics have their own effective ways of learning that are aligned to their characteristics. The claim that cooking is best taught in the kitchen (Solomon, 1980) reveals this position clearly. With systems science instruction, teachers would have strong backgrounds in the content area, which will be a solid foundation for the teaching of Earth systems science.

Second, pre-service teachers will have a sounder understanding of the nature of Earth systems science with teaching based on this methodology. Understanding the nature of science is an important learning objective in modern science education. Therefore, Earth systems science teachers should be equipped with a sound understanding of the nature of Earth systems science. This will contribute greatly to the teaching of the nature of systems science implicitly or explicitly. Both will contribute greatly to the proper and balanced practice of teachers in science classrooms.

Many themes in Earth systems science could be taught more effectively through abduction or systems science methodology. To do this, college teachers should be clearly aware of abductive inference. Some Earth science topics have already been taught according to systems science methodologies. Sometimes following this method is inevitable in Earth science classrooms if a teacher is trying to follow the real procedures of Earth systems science inquiry. However, only a few realize that they are following systems science methodologies. Therefore, many still believe that they are following the (stereotyped) inquiry method, even though they use systems science methodology. Clear awareness will greatly enhance the direction and/or practice of Earth systems science teaching.

Course syllabi and lesson plans are developed based on the systems science methodology. Systems science methodology may be taught as an introduction to the general aspects of Earth science at the beginning of a course. It can provide basic information to pre-service teachers on what the systems science methods are, and will be a foundation for the later part of the course.

A typical example of Earth systems science methodology teaching is as follows: data/ phenomena are presented or described first, hypothetical contexts are sought or summarized, possible hypotheses or theories are brainstormed, appropriate ones are selected, and the data/phenomena are explained or interpreted, hence provide best explanation. Systems science methodology can be applied to any form of instruction, such as lectures, laboratory experiments, field trips and so forth. However, field trips or data interpretation activities are typical forms of instruction that follow systems science methodology. For example, students identify minerals with polarizing microscopes in an Earth science laboratory. They describe a certain mineral as optically isotropic (data described). The mineral is a part of a coarse-grained rock neither altered nor metamorphosed (hypothetical context). The possible laws that could be applicable to this situation are: (1) crystals of the cubic crystal system are optically isotropic, and (2) glass which results from quick cooling of a silicate melt is optically isotropic. As the mineral is a part of an unaltered coarse-

grained rock, the first law is selected and applied. The mineral is classified as a cubic crystal system.

3.2. Systems science method and instructional strategies

Science teachers who want to use systems science methods in their classroom should be familiar with instructional strategies that employ abductive inference. There are at least two approaches with abduction: the empirical-abductive (EA) learning cycle by Lawson, et al. (1989), and the abductive inquiry-learning model by Kim (1997).

3.2.1. The empirical-abductive learning cycle. The empirical-abductive learning cycle (EA learning cycle, Lawson et al., 1989) is the first instructional strategy that employs abduction. Lawson et al. proposed three types of learning cycles: descriptive, empirical-abductive and hypothetical-deductive (1989) which represent three points along a continuum from descriptive to experimental science (p. 47). The learning cycle is known to have three phases: Exploration, Invention (Concept Introduction), and Discovery (Concept Application). In the Exploration phase, students participate in activities that emphasize direct experiences with materials or phenomena. The second phase, Concept Introduction, follows Exploration and the teacher relates scientific concepts directly to the pattern discovered by students during the Exploration phase. The last phase, Concept Application, requires students to apply the new concepts learned to additional examples. The EA learning cycle also has the same phases as the learning cycle. In addition, the EA learning cycle has the following characteristics (Lawson et al., 1989).

> In empirical-abductive learning cycles students discover and describe an empirical pattern in a specific context (exploration), but go further by generating possible causes of that pattern. This requires the use of analogical reasoning (abduction) to transfer concepts learned in other contexts to this new context (concept introduction). ... With the teacher's guidance, the students then sift through the data gathered during the exploration phase to see if the hypothesized causes are consistent with those data and other known phenomena (concept application) (p. 47-48).

The learning cycle is an excellent learning model based on sound philosophical and psychological grounds, and has been studied for a long time and used widely. The EA learning cycle reflects abductive inference quite well, such as the collection of data at first, and then advances hypotheses. Lawson et al. focused on causal goals rather than historical ones when they introduced the EA learning cycle. It may be inevitable because it is based on a learning cycle that emphasizes scientific concept formation. Science concepts usually result from causal inquiry. Chronicles, the results of historical inquiry, are reconstructed from data often with causal laws and concepts, but are not applicable to other examples or cases, because they are unique in time and space. Therefore, the EA learning cycle is very effective in dealing with causal inquiries in Earth systems science classrooms, but faces some difficulties with historical inquiries.

As an example, a lesson about global climate change is illustrated. Two questions, one descriptive, and the other causal, are raised during the Exploration phase.

(1) Descriptive question: What is the general trend of global temperature change?

(2) Causal question: What causes global temperature change?

Students are then challenged to read and interpret the data on global temperature change presented by the instructor to answer the first question. Students can describe the general pattern of global temperature change after the Industrial Revolution. They can also discover that the increased concentration of CO_2 in the atmosphere is related to the increase in temperature. The students are then reminded of the second question: What causes global temperature change? At this point, information on the ability of CO_2 to trap the heat radiated from the Earth can be provided. Students try to answer the second question based on the results of the first question, their experience and related information. Some of them perhaps scrutinize similar cases from their experience and knowledge such as warm greenhouse, or the high temperature and the high concentration of CO_2 in the atmosphere of Venus, and formulate a hypothesis of greenhouse effect by analogy.

3.2.2 Abductive learning model. Kim (1997) developed a teaching strategy based on abduction. He summarized abduction as having four steps: (1) exploring/observing phenomena, (2) examining or formulating possible hypotheses, (3) selecting the most probable hypothesis, and (4) explaining the phenomena. Based on this, he proposed an abductive learning model with four phases.

The first phase is 'Exploration'. In this phase, the places or materials to be explored by students are selected or prepared in advance of the lesson. Teachers have to make it clear that the places or materials selected can provide experiences or data to students that are appropriate to meet the learning objectives. Students explore the phenomena and collect data, and arrange them in a meaningful form. The data form the basis for the activities in the remaining phases.

The second phase is called 'Examining'. In this phase students are asked to seek possible hypotheses, scientific laws, or principles, which may be used to explain the phenomena investigated during the previous phase. Teachers could assist students' effort by providing some possible hypotheses or scientific laws or principles, if students have difficulties in locating them. Sometimes relevant and irrelevant hypotheses or scientific principles could be provided at the same time for students to review. Students often rely on their previous experiences and prior knowledge during this phase.

The third phase is 'Selecting'. In this phase, students select the best hypothesis to explain the phenomena. After examining all possible hypotheses or principles, students would select the hypothesis that best satisfies the hypothetical context, or exclude hypotheses that do not, based on their compatibility with the problem context.

The final phase is 'Explaining'. In this phase students are expected to explain the phenomena observed with the hypothesis or principles selected in the previous phase. In this process they may reconstruct the past events that occurred in the place investigated. In causal inquiry, students usually explain with the hypothesis selected how current geologic features are formed.

The abductive learning model can be used for both inquiries, historical and

causal. Therefore it is more flexible and applicable than the EA learning cycle, which is suitable for causal inquiries. Theories of continental drift, for example, can be approached with the abductive learning model. The distribution of fossils, such as *mesosaurus*, *glossopteris*, and so on, in the continents of South America and Africa is presented to the students. The jigsaw fit of South America and Africa could also be stressed. Distinctive sequences of rocks on one side of the Atlantic are identical to rocks on the other side. Students are encouraged to develop hypotheses on this. Examples of some possible hypotheses formulated by students are provided below.

(1) Animals had crossed the ocean by swimming, and the seeds of plants had crossed by wind..
(2) There had been land bridges between the two continents, and animals and plants moved over the land bridges
(3) There had been island chains between the two continents, and animals and plants moved by using the islands as stepping-stones.
(4) The continents had been connected in the past, but they moved apart very slowly.

If students fail or have difficulty in developing hypotheses, then several hypotheses from the history of science, such as the land bridge hypothesis, or continental drift, may be provided. Class discussion will lead to select the best hypothesis. The jigsaw fit of the two continents could provide guidelines to eliminate less appropriate hypotheses. The continental drift hypothesis might be selected. Finally, the history of this region can be reconstructed. The continents were united in the late Paleozoic, and broke apart very slowly.

3.3. Learning to use systems science methodology in science classrooms

Systems science methodologies for instruction should be introduced to pre-service teachers, who will eventually teach science in the classroom. There must be various ways to introduce systems science teaching strategies effectively. An effective approach makes them understand the abductive inference and background of the strategies and provide chances to practice applying the strategies.

First of all, pre-service teachers have to understand abductive inference and its background. Abductive inferences in Earth systems science and everyday life can be explained to and identified by them. They will understand by experience that abduction is incomplete logically but highly probable practically. They also understand that we use abductive inference very frequently in science and in everyday life to explain and understand events and phenomena. The followings are examples explaining abduction in everyday life and science.

Abductive reasoning is frequently used in ordinary life. When we infer some fact about a person's mental state from his or her behavior, we are inferring that the fact explains the behavior better than some other competing explanation does. Consider the following dialogue.

A: Why are you pulling into the gas station?
B: Because the gas tank is nearly empty.
A: What makes you think so?

> B: Because the gas gauge indicated nearly empty. Also I have no reason to think that the gauge is broken, and it has been a long time since I filled the tank.
> Under the circumstances, the nearly empty gas tank is the best available explanation for the gauge indication. B's other remarks can be understood as being directed to ruling out a possible competing explanation (broken gauge) and supporting the plausibility of the preferred explanation (Josephson & Josephson, 1996, p. 6).

Abduction is also frequently used in science. Lawson et al., (1987) documented numerous examples of abduction in the history of science.

> Kepler borrowed the idea of ellipse from Appolonious to describe planetary orbits. Mendel borrowed patterns of algebra to explain heredity. Kekule borrowed the idea of snakes eating their tails (in a dream) to determine the molecular structure of benzene, and Coulomb borrowed Newton's ideas of gravitational attraction to describe the electrical forces which exist at the level of atomic particles. (Lawson et al., 1987, pp. 24-25).

Next, instructional strategies and their backgrounds are introduced to the pre-service teachers. As they already have basic understanding of abduction, the phases of the strategies and major activities of each phase are emphasized. With the explanation of the phases of the strategies, typical examples with the characteristics of abduction strategies have to be provided. Teachers could have chances to understand and discuss the examples. The case on continental drift dealt with in section 3.2.2 could be used as an example.

Third, a description of a lesson based on abductive inference is provided. In the lesson, the phases of the abductive learning model are not specified explicitly. Pre-service teachers are asked to identify the phases of the model in the lesson. In small groups, they can discuss their division of the lesson into the phases of the model, and present their conclusions to the whole class. An example of a lesson is provided in Table 2.

Table 2. An example of a lesson for students' activity

1. The objective of the lesson is presented: To discover the structure of the Earth.
2. A diagram which shows the velocities of P and S waves in the crust, mantle, outer core and inner core of the Earth is presented to the students. The property of seismic waves, such as diffraction and reflection, is introduced if not dealt with previously.
3. Students interpret the diagram.
4. Students formulate possible hypotheses.
5. Students present their hypotheses to the whole class.
6. Students select the best hypothesis through whole-class discussion.
7. Students explain the interior of the Earth.

Students may place 1, 2 and 3 in Table 2 into Exploration, 4 into Examining, 5 and 6 into Selecting, and 7 into Explaining.

As they are ready to develop lesson plans with abductive strategies, several learning themes are provided with grade levels to be taught. Pre-service teachers are encouraged to develop lesson plans on a theme they select. Lesson plans developed have to be reviewed by a small group of peers in terms of abduction. They revise lesson plans according to the feedback. Microteaching could also be applied with the lesson plan. Pre-service teachers usually share their ideas and have chances to

practice abductive teaching strategies.

4. CONCLUSION

Systems science methodology, frequently used in Earth systems science, is quite different from the stereotyped ones that emphasize controlled experiments, and is known to contribute substantially to the development of science. Abduction and the hermeneutic circle suggested by researchers as a major method of systems science methodologies were reviewed and discussed in this chapter.

Systems science methodology is very important for teachers for the following reasons. First, if systems science methodology is used in the classroom, it will contribute greatly to students' perceptions on the nature of science. In spite of various philosophical positions on the nature of science, many science educators are confined to very narrowly defined views on the nature of science, which emphasized controlled experiments based on falsification. With systems science methodology, students may have more balanced and unbiased views of the nature of science.

Second, it fosters students' scientific thinking skills as discussed in the first chapter of this book by Mayer. Frodeman (2000) states that Earth sciences provide a model of reasoning, abductive inference that is more attuned to the realities that we face in our daily lives than the physical sciences. Abductive inference is frequently used in ordinary life as well as in scientific research. Sound understanding and proper application of abductive inference to everyday life or science learning will greatly contribute to the development of scientific thinking skills for the average citizen.

Third, it can provide effective ways of teaching or learning Earth systems science. The abductive learning model reflects the inferences frequently used in Earth systems science. Therefore, this method is well aligned to the characteristics of Earth science content, and hence it provides effective ways of teaching Earth science.

To use systems science methodology in the science class, teachers are equipped with instructional strategies based on systems science methodology. The EA learning cycle and the abductive learning model are two examples. Both strategies emphasize data collection and analogical reasoning. However, it is an initial stage for both models; they need to be exposed to more investigations in the classroom and improved in terms of psychological and practical grounds.

Abduction, frequently used in Earth systems science, could also be applied to other domains of science. Many topics in life science and some physical science themes are taught more effectively with the abductive learning model.

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CHAPTER 18: GLOBAL SCIENCE LITERACY TEACHER ENHANCEMENT PROGRAMS

Victor J. Mayer, The Ohio State University, USA

1. INTRODUCTION

With the extensive changes in university structure that would be necessary for the implementation of programs to prepare science teacher for a unified program in global science literacy, it is unlikely that such programs could be developed, at least in the near term and within the political structure of American universities. It is incumbent therefore on science educators to be able to provide in-service teacher programs that adequately foster the background in knowledge of the earth system and provide the experiences in the learning environments that are appropriate for their students. In this chapter I discuss the structure of two model in-service programs for Global Science Literacy. They are based on programs that were developed and implemented in the 1990's for preparing teachers for developing and implementing Earth Systems Education curricula. To provide some assistance to teacher educators wishing to prepare teachers for GSL, they have been modified and updated to be appropriate for preparing teachers in some of the goals and objectives of GSL.

If we expect to assist in-service teachers in achieving the objectives and goals of Global Science Literacy for their students through an intensive workshop experience, the structure and content of the workshop will need to be carefully considered. It must employ instructional systems and learning environments that are consistent with those we expect the teacher to use with his or her students. One of the most important is cooperative learning especially the form called 'jig-saw'. This type of cooperative learning strategy, closely emulates much of science investigation. Since GSL curricula are conceptually organized around the concept of the "Earth as a system" the field also becomes an important learning environment. Thus GSL workshops need to incorporate extensive field experiences. Other important learning environments are the Internet, authentic assessment and effective reading materials. In the latter case, we have begun developing materials initially inspired by the "Beyond 2000" project of Kings College, London, entitled "explanatory stories" (King, 2002). We have modified the concept for use with GSL programs. The type of story developed by King has been adapted as a "teacher guide" to the development of essential earth system concepts. Correlated with each teacher guide we are providing some student readings to take the place of the traditional textbook. These student materials are designed to elicit student interest and involvement in the teacher conducted activities specified in the teacher guide. They are not designed to teach the students the concepts by themselves. We now label these materials as "exploratory stories" based on the nature of the student materials.

The two programs that we are basing our teacher education models on were a summer workshop and a full yearlong in-service program designed to accomplish many of the objectives of the summer workshop.

2. A MODEL FULL-TIME WORKSHOP FOR GSL IN-SERVICE TEACHER PREPARATION

An ideal way to work with teachers in developing alternative views of the nature of science and the science curriculum and teaching is through their full-time involvement in a program. This is normally only possible in the interval between two school terms. In the USA this is invariably during the summer months, June through August. Other countries will have different periods when such full time experiences many be offered. The length of time available will vary also according the source and amount of funding and the nature of the contractual relationships between school administrations and teachers. Such summer workshops in the USA are often funded by the federal government through the National Science Foundation or through the Eisenhower program of the Department of Education. Occasionally, local school districts might make short one-week workshops available at the end of the school year.

The model workshop discussed here is based in part on a three-week long workshop supported by the National Science Foundation. The grant supplied the operating costs for the workshop, living expenses and modest honorariums and traveling expenses for the teachers since they came from a number of states east of the Mississippi River. A companion workshop was being offered at the University of Northern Colorado in Greeley for those teachers from west of the river. The model workshop described here is based on the university campus. This is often advisable because of the extensive personnel and materials resources that are available at major universities in the USA, especially those with extensive teacher preparation programs. Often student dormitory space will be available to house the teachers. Also, with relatively few undergraduate students on campus, classroom and laboratory facilities will be available for the teachers' use. If conducted for a school system or for teachers in a restricted geographic region, other facilities could be used such as those of a local high school.

In organizing the workshop we used a cooperative learning organization similar to that described by Johnson and Johnson (1975/1995)) as the "jigsaw". In fact, this type of organization has become standard in Earth Systems and GSL programs (Fortner, 2002). Since the program occurs during the hot summer months, we have found that it is best to start early in the morning, usually no later than 8:00 AM. With air-conditioned classrooms and laboratories formal sessions can be carried on over the full day, usually ending by 4:00 in the afternoon, but with frequent sessions also in the evening. When not in formal group sessions, teachers are provided with meeting space, either in the dormitories or in classroom facilities to do independent and cooperative group work.

Since an essential aspect of cooperative learning is teamwork, careful consideration must be made in organizing the teams. In the NSF program we selected teams of three to five teachers from a particular school system or locality into the program. Each team included elementary, middle school and high school teachers. These "local teams" were the fundamental organizational units both during the summer workshop and later as the members conducted short workshops in their own states and school systems. One of the desired outcomes of the summer workshop should be for

individual members of each team to develop a team identity and spirit. This will help them through the ensuing school year when they are adapting new curriculum and teaching methods. They will have a collegial support system.

Each team also identified a school administrator and a college faculty member from their area. They were team liaisons, assisting the teachers in a variety of ways during the year following the summer workshop. Liaisons were brought to campus for two days mid-way in the summer workshop to consult with their teams and to plan activities. This demonstrates an important aspect of science curriculum change. Administrators must be personally involved in some way. We chose to bring them to the workshop itself. If this is not possible, a series of short briefing sessions should be conducted for selected key administrators and supportive professors of local colleges and universities, where they are instructed on the goals, objectives and requirements of the new curriculum thrust.

Although the NSF program was a national program, similar elements of team structure can be developed and implemented on a state or district level. At the district level, for example, a program might draw from three or four high schools in the district. Teams could be set up, one from each high school consisting of the teachers of the various science disciplines. These would be the local or school teams (base teams in the Johnson terminology). The specialist teams would be based on each of the three or four disciplines. With the chemistry teachers from each of the high schools in one expert team, the earth science teachers in another and so on.

2.1. Team Organization

In the model full-time program, there are three levels of organization. The first is the base group. In the NSF program it was the three plus teachers from a school system. The second is the "expert group" Here it was the teachers from a particular grade level, elementary, middle school or high school. In the third grouping, several base groups were brought together to work with the scientists.

In the NSF program the teacher teams were assigned to these groupings as follows:

Base Group - This is the original group that was accepted into the program. Most area or district teams had three members representing three different grade levels; elementary, middle school, and high school. These were the base groups in Johnson and Johnson terminology. Later in the summer workshop the team was joined by an administrative liaison and a college liaison. We found that administrative understanding and support are often essential for teachers to bring significant change to their science programs. The college consultant could provide follow-up services to the teachers on an individual consulting basis, or in some cases, develop and implement earth systems workshops for the school system. Each area or district team was named for its state or local community.

Combined base-group - For certain purposes, two or more base groups joined into four larger groups each including teachers from all three teaching levels. It is useful to label each of these groups with a name. In the NSF program we

called the four groups that resulted, the Ancients, the Interactives, the Aesthetics and the Stewards after four of the Earth Systems Understandings (See Appendix A).

Expert group - For certain purposes, groups were formed of all participants who taught at the same grade level. They were named for their grade level. In more general terms these would be the expert groups since they can bring considerable expertise to the development of programs in their particular grade level.

These teams then function much in the manner of the "Jigsaw II" approach described by Aronson (1978) and elaborated upon by Slavin (1987). That is, those teams that have specific knowledge on a science topic are charged with the responsibility of teaching it to others in a team with teaching level (background) similar to their own, the expert group. Although in the NSF program, we arrived at our organizational and program pattern independent of these two sources because of the unique nature of the student population and needs of the program, the process used was similar.

In our example of the program involving the high schools of a school district, the science teachers from each high school might form the base groups since we would hope that they would be working on the development of a GSL program for their particular school. The teachers of each discipline would form the larger "expert" groups. For example, the chemistry teachers would from one expert group, the earth science teachers another, and so on. For certain purposes the base groups (teachers from a school) would be combined into the combined base groups.

2.2. First Phase of the Full-time Workshop - Earth Systems Science

In our model workshop, science methodology and content is the focus for the first week. The workshop organizer will need to identify the science topics that will be the focus for the workshop, using the science standards as organized in the diagrams to be found in Chapter One of GSL (2002). Ideally, there should be four different, but related topics focusing on the Earth system. Four scientists need to be available full time during that week; a specialist in each of the topics. For example, in the first year of the NSF workshop the scientists at the Columbus workshop were Dr. Susan Humphris of the RIDGE project at Woods Hole, Dr. Glenn Izett of the United States Geological Survey, Dr. Ellen Mosely-Thompson of the Byrd Polar Research Center at The Ohio State University and Eilene Shea from NOAA's Global Change Program. Each of the scientists spent the same three to four days with us informally and formally discussing their area of expertise. Dr. Humphris was investigating the geology and biology of the deep sea vents that occur along the Mid Atlantic Ridge, Dr. Izett the suspected Cretaceous impact crater on the Yucatan Peninsula, Dr. Mosely-Thompson ice cores and their implications for global climate change and Dr. Shea global change projects and policies in Washington.

At the beginning of the first week, each of four combined base group teams is given a different set of readings from journals such as *Scientific American* corresponding to the research area of one of the scientists. For example, the Stewards were to meet later with Dr. Humphris and to learn about deep-sea vents and their

associated life systems. Team members read each of the articles prior to their first group meeting. At the group meeting they discuss the articles. Those with a deeper background in science, such as the high school Earth science teachers, help the others with terminology and concepts that may be difficult, especially for the elementary school teachers. The charge to each member of the group is to become a knowledgeable in their particular science topic because they will be responsible for teaching it to members of their base groups who will not be familiar with the topic. As a group then, their final action of this phase is to develop a series of questions that they need answered about the topic. This sets the stage for the next part of the learning process. Now their scientist will spend time with them to answer the questions they have as a group about their science topic. This also provides an opportunity for the scientist to delve deeper into the current implications of her research in the topic. Each of the four combined base groups function in this way, but with a different topic and a different scientist.

Once all of the four combined base groups have completed this first stage of the learning process, they reassemble into expert (grade level) groups. Representatives from each of the four combined base groups in each of the expert groups are then responsible for teaching their topic to the other members of their group. They will usually adapt the content of the particular topic to their group members= backgrounds. For example, the elementary level instruction will focus more on the broad processes behind the topic, rather than the specific type of research being done and research procedures used. This latter will be more common in the high school group. Instruction in the topics needs to be arranged so that no two expert groups were working on the same topic at the same time so each scientist could be a resource person to each of the expert groups as they were discussing his/her topic. This also gives the teachers an opportunity to work with each of the four scientists on a small-group basis.

A series of field investigations were conducted also throughout the program. In the first week, they focused on local earth system features. In Ohio, teachers investigated glacial features as indications of climate change. Colorado teachers studied the evidences of the Cretaceous impact preserved in the K-T boundary and evidences of dinosaurs revealed by tracks and fossils.

The third stage of this process is a large group lecture by each of the scientists on her/his particular topic. Lectures occur after all teachers had been brought up to date on the topic through the cooperative learning process. The scientist is therefore able to tie together the key points of the topic and to review the research area. The final stage of the process can be a panel discussion where all of the scientists ask each other about their research and engage in discussions with the teachers. During the NSF program this panel discussion delved into the teaching of the topic and some general concerns about the science curriculum and the place of Earth Systems content within it.

This approach to the teaching of science topics means that teachers are able to grapple with topics in an interactive cooperative environment. Through discussions they verbalize their understandings of science concepts, have them challenged, defend them, and change them if necessary. They also are able to interact with scientists in a small group setting rather than just sit and passively listen to them. The scientists in turn are able to talk with teachers about particular problems they have in teaching science

concepts and their work schedule, and school environments. In the NSF program the scientists discovered that the teachers were bright, well informed and interested in science and their students. They left with a better idea of the quality of the teachers and the problems they faced in working with students, parents and administrators.

2.3. Phase Two of the Workshop – Curriculum development and resource identification

The focus for the next phase of the workshop will depend on its overall objectives. If the intent is to assist teachers in eventually developing a GSL based curriculum for their school or school district it will be important for them to focus on the location, organization and the development of materials. The first objective, however, will be to develop an overall framework for the curriculum. One week, or even three weeks, will not be sufficient time even for that beginning step. However, it must be started. In our model workshop, therefore, we propose that the second phase be an educational research and development phase. In other words, teachers need to be given the opportunity to discuss and share ideas, to search for and discover already development materials that might be appropriate for use in a GSL curriculum, and to interact with science educators who have special background and preparation in GSL curriculum design. To assist in this purpose each team should start by using the appropriate GSL concept organization guide for their particular school organizational level. (Include diagrams from chapter One GSL 2002 here?).

In the NSF program, our objectives were not quite so global. The goal of the workshop was simply to assist teachers in identifying and using Earth Systems classroom activities. However the procedures we used can be adapted for programs with the much more global goals. In the NSF program each base group developed a resource guide for infusing Earth systems materials into their own curricula and for providing assistance for that purpose to other teachers in their locale and state. This actually, might serve as a first phase for the more global program. They were given the following instructions:

> In developing the guide, teams will work with other base groups and be organized into different groupings for certain activities; each base group, however, is expected to submit a unique resource guide that capitalizes on the team members' special talents and interests.
>
> Choose one of the following **systems as a focus** for your guide; lithosphere, biosphere, hydrosphere, cryosphere, atmosphere, or solar system. Identify a **theme** within the system. Examples of themes in the hydrosphere might be rivers, oceans, and lakes. Develop the theme to be appropriate for each of the three grade levels. An example from the river theme might be, local stream (elementary), local river system (middle school), North American river systems (high school).
>
> For each of the three grade levels develop a maximum of **five questions** about the theme for each of the **seven Earth Systems Understandings**. Each question should elicit a significant concept, skill, or attitude regarding the subsystem. Questions eliciting yes/no answers or memorized details should be avoided in favor of investigative and open-ended questions.
>
> For each of the seven Earth Systems Understandings at each grade level identify ONE **EXEMPLARY student activity**, ONE **teacher background resource** and ONE **audio-visual,**

literature or art student-resource that will satisfy one or more of the questions you have defined. The student activity must be especially useful for the designated understanding although it might be helpful for others as well. Each team's resource guide, therefore, should have up to **seven activities** identified each at the elementary, middle school and high school level.

Participants were cautioned neither to be exhaustive for the chosen theme nor to include all of the possible questions or references. Instead, they were to be thoughtful and selective--to emphasize quality instead of volume. Activities chosen were to actively involve students in the topic or concept. Worksheets were not acceptable. Teachers were also to provide complete references to all materials.

An extensive set of Earth Systems Education resources was available for the teams' use from a library maintained especially for the workshop. The library included teaching materials such as the GEMS and CEPUP materials developed by the Lawrence Hall of Science, science references such as Stephen Gould's *Wonderful Life*, environmental materials such as those published by The World Resources Institute, books of art and photography such as *Nature's Chaos* by Eliot Porter and James Gleick, and many other types of useful teaching resources. The university libraries and other campus collections were also available. In addition, participants were encouraged to bring their favorite instructional resources to use and share. One of the most useful sources was the Internet, especially for science content and information, and databases to be used in classroom instruction. At the end of the workshop each area team provided a copy of its resource guide to each of the other teams, so all participants had an extensive set of resources and ideas about teaching Earth Systems understandings. During this phase of the workshop the base groups did the primary work. Periodically, however, the participants met in their four expert teams to get a broader range of experience and expertise focused on the search for materials and the appropriateness of the topics being developed for the particular grade level.

Field trips were continued during this week. Visits were arranged to science laboratories where earth systems investigations were being carried on, such as those of the Byrd Polar Research Center at Ohio State. In addition a field trip was taken to a new high school facility were teachers were able to talk with the teachers and visit their 'cutting edge' teaching facilities.

2.4. Phase Three – Two alternatives

For the third phase or week of the model full time workshop there can be several alternatives. One might be simply to carry on the activities of the first two weeks. In other words, the first, or content phase of the workshop might be expanded into the second week and the second phase, or curriculum development phase started toward the end of the second week and continued on into the third week. This would be advisable, if the workshop was enrolling most or all of the teachers in the schools of a particular district such as our earlier example of the science teachers of the high schools of a local school district.

If the full-time program is of a broader scope, such as the NSF program that

drew from a national population of school districts, or is designed as a leadership program for a school system, the participants will be "representatives" of schools, not the full school staff. Therefore there will be a need to provide some leadership training as we did in the NSF program.

It was designed to assist the participants in developing skills to enable them to present their own Earth Systems Education programs when they returned to their states and localities. Following some suggestions provided by the workshop faculty, each of the four base groups developed a plan for a three-hour workshop. Each group then presented its workshop to the other base groups meeting in a combined group format. This series of practice workshops was the final phase of the summer program. Teachers were able to critique each other's presentation style, provide additional suggestions for materials to use and program elements to include. Some teachers had to overcome a certain amount of "stage fright" in order to complete this phase of the program. We encouraged the less experienced teachers to do most of the presentation so that the "old-timers" did not dominate them and so that those that really needed the practice and experience received it. In addition the potential teacher leaders need to be apprised of a variety of models of curriculum innovation and design and assisted in developing the personal competencies to design and conduct innovation programs within their school districts.

3. ADAPTATIONS FOR THE IN-SERVICE PROGRAM

The basic organizational ideas of the full time workshop can be adapted for a program that will take place during the school year when teachers may meet following classes during the week and on Saturdays. Take for example, a program developed for middle and junior high school teachers in a metropolitan area. In this case, each team can be a school district team including team members from two or three grade levels. The program should be structured so that the teachers meet alternatively in school district teams (the base group), grade level teams (the expert groups), and multi-level groups (the combined base groups) similar to those discussed below.

The in-service program model is structured over the full school year. Teachers would meet as a group for ten to fifteen Saturday mornings. In a program conducted in the Columbus area, we used a format under which the Saturday meetings were normally held in three successive components. Normally the morning was begun with a large group format where a consulting expert would discuss or conduct an activity on a science or science education topic. This was followed by breakout groups of either the base groups or the expert groups (depending on topic) where a series of questions based on the large group activity were discussed. The scientist or educator presenter would move among the groups, responding to questions or elaborating on certain topics. The program coordinators would also visit with each of the groups to assist discussions.

The teachers were expected to analyze and develop modifications of their existing curricula based on the philosophy of GSL. In the second component of the Saturday meetings they would meet in the grade level groups to share instructional information across school districts and to discuss the topics of the general session. Often this session ended just before lunch. In the Columbus workshop, lunch was arranged

on site by the workshop coordinators. The participants met together during lunch to discuss plans for future workshop activities. They did this under the leadership of a lead teacher, one of the participants. Often the workshop coordinators would participate in the discussions, but never dominate them. Following lunch, the participants would engage in the third component. Here they were organized in their school district groups. The purpose was to integrate any information about content and materials learned in the earlier two components into their science teaching and/or curriculum.

During the following week, each of these base groups was to meet for at least one hour in their school following the end of their classes. The purpose was to provide planning and evaluation time for reflecting on their curriculum revision and development efforts.

The Saturday meetings alternated with meetings on the university campus and in the participating school district facilities. Several of the Saturday meetings involved field trips to interesting earth system features such as local fossil localities, school outdoor education facilities and local natural park areas.

4. CONCLUSION

We found working with American teachers that they had a great deal of difficulty in the team and collaborative working situation--especially since we expected them to take leadership in identifying the activities that they were to engage in and the evaluation of the results of their efforts. In general, they seemed to expect the workshop coordinators to exert control over all of the workshop processes and to tell them what was expected of them along the way. Many seemed to have difficulty with accepting the idea that they were the judges of their success using the evaluation criteria that were provided by the workshop coordinators.

We found during the first NSF workshop held in Columbus that many of the teachers had a difficult time adjusting to a program requiring them to take responsibility for a major part of the teaching and learning. They were highly conditioned to being told what to learn and how to learn it. Therefore for subsequent workshops we provided some very extensive pre-workshop information. This included a booklet entitled *Earth Systems Education: Origins and Opportunities* with all of the articles referenced at the end of this article. In addition a brief description of the program was developed and sent out at least a week or two prior to the start of the program. Following are some quotes from the description:

> CONGRATULATIONS!!! YOUR TEAM HAS BEEN SELECTED FOR PARTICIPATION IN THE SUMMER WORKSHOP IN THE PROGRAM FOR LEADERSHIP IN EARTH SYSTEMS EDUCATION.
>
> Notice our emphasis on **TEAM**. This should be the first indication that this will be different than workshops you may have participated in prior to this summer. The entire program uses a **collaborative teaching model.** We will seldom schedule lectures about science, teaching methods or learning theory. Instead you will interact with scientists, pass on information from them to other members of your team (peer teaching), engage in developing a resource guide in Earth Systems Education with your team (thus learning about the Earth Systems Education philosophy) and develop and

> present a model workshop while on campus (thus learning the ins and outs of workshop development and presentation from your teacher peers).

They were warned that this was a lot to accomplish in a mere three weeks. We then provided them with an overall view of the three-week program. We concluded the description with:

> We are confident that this summer's experience will be a valuable one for your team and will leave you with a new excitement for teaching about the Earth System. Bring your creativity, your enthusiasm, and a team spirit with you.

Despite the forewarning and the extensive informational material sent to participants prior to the beginning of the NSF workshop, it invariably took the first week for most of the participants to understand the process we were using and to appreciate its efficacy. Some never did, but they did understand the reasons for it, and at least "went along" with the program. We came away feeling that it was the ideal format for a workshop. The time was very short however, and it may take more time to get most teachers accustomed to the type of responsibility that is expected for this type of format so we would recommend that, given the resources, the term of the full-time workshops should be at least four to five weeks long.

The teachers enrolled in the in-service program had much less difficulty with the organization of the workshop and with taking major responsibility for planning the activities included in the program. This may be because of their familiarity with the workshop coordinators, one of whom was an area middle school teacher. In the NSF program, the workshop leaders were unknown to the participants prior to the beginning of the program. In this case trust needed to be developed, but very little time was available to accomplish this.

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CHAPTER 19: TEACHING GLOBAL SCIENCE LITERACY: A PROFESSIONAL DEVELOPMENT OR A PROFESSIONAL CHANGE

Nir Orion, Weizmann Institute of Science, ISRAEL

1. INTRODUCTION

Global Science Literacy is an alternative framework for the science education curricula. Like other (older) alternatives it emerges from the new "Science for All" paradigm, the constructivist movement and the Standards (Mayer, 2002; Mayer and Fortner, 2002). The current reform in science education joins several previous reforms, which started about forty-five years ago, while the world attention was brought to bear upon science education with the launch of Sputnik in 1957. Since that "wake-up" call science education policy worldwide has been focused on the need for new curricula, new instructional materials, new reforms, and new approaches to learning and teaching science. The development of the science education does not go in a linear gradual line. Rather, it goes through series of reforms that rise in cycles of about ten years. However, these reforms do not cause a punctual development, since they are characterized as what is called – the pendulum effect. This means that they do not have a pattern of a linear progression. Rather, in each decade, before the existing reform came to maturation, a new one that turned the science education field towards a different direction replaced it. There are several reasons for this pattern of reforming, but there is no doubt that teachers are a central factor for the success or failure of any educational reform.

2. THE CHARACTERISTICS OF A GLOBAL SCIENCE LITERACY TEACHER

The teaching strategies of Global Science Literacy are quit different from the traditional way of teaching science (Table 1).

Table 1. A comparison between the traditional science teaching and the GSL teaching

Traditional science teaching	GSL teaching
Prepare the future scientists of a society	Prepare the future citizens of a society
Disciplinary-centered teaching	Multidisciplinary teaching
A teacher-centered teaching	A child-centered teaching
Content-based teaching	Integration of skills within contents
The teacher is a source for knowledge/information	The teacher is a mediator for knowledge
"Chalk and talk" based teaching	Inquiry based teaching
School-based learning	Multi learning environments: Classroom, lab, outdoors and computer.
Teaching that is derived from the scientific world	Authentic based teaching derived from the real world

Traditional assessment		Alternative assessment

For many traditional science teachers all over the world, the implementation of the new "science for all" programs in general and the Global Science Literacy approach in particular is not just a professional development. The meaning of professional development is that the subject of the development, in our case science teachers, have a very solid basis of their profession and from this professional core they can grow and expand. However, in order that teachers will move from the right column of Table 1 to its left column, even in relation to some of the six parameters, they have to change their goals, contents, ways and philosophy of teaching. Moreover, the shift presented in table 1 is valid for any genuine "Science for All" teaching, however the GSL teaching demands on top of it two additional new aspects for teachers: (a) Teaching earth systems subjects, which many science teachers in may countries have no scientific background and (b) the using of the outdoor learning environment, which is also ignored by most of the traditional science teachers. Thus, the shift from a traditional science teacher towards GSL teacher is not just a development rather it is a major reform or even a revolution.

It is suggested that at least in relation to the current "science for all" reform, the using of the term professional development is misleading and contributes to the difficulties of making a genuine change in teaching style and focus.

3. THE STUDY

During the last 10 years the author has invested a lot of time and energy within the "storm's eye" of the new Israeli "Science for All" curricula for the junior high school and for the high school. This intensive work has included participating in the committees that designed the new "Science for All" curricula; taking a central role in a team that has developed learning materials for these two programs; leading and taking a practical role in hundreds of in-service training hours in each of the last 9 years both in in-service training centers and in the teachers' schools and classes. Moreover, the main goal of those in-service training programs (INST) was to introduce the new "Science for all" approaches and curriculum materials including some aspects Global Science Literacy.

During our long-term study we explored several models of INST programs. These models were designed for helping or in many cases to push science teachers to adopt new strategies that are in agreement with the "Science for all" approach and to implement the new learning materials that were specifically developed for the new program. More specifically the study was focused on two types of long-term in-service training courses. Both types were designed for 720 hours (one day a week over 3 school years). The first type included INST programs that were conducted in regional teacher centers established countrywide, while the second type included school-based programs. Each of the courses in the regional centers consisted of about 20 teachers who came from different schools. Since only rarely the whole science teachers' team arrived to the course, the working within the schools was

limited and the teachers were expected to update their colleagues and to convince them to adopt the new approaches and learning materials.

The second type was an in-schools INST program. This program included the whole science teachers' team and focused on implementing new strategies and curriculum materials through working with the teachers in their classes in real time. The in-school INST was based on a holistic approach of dealing with all the aspects of implementing a reform within the school. Before, implementing the INST the head master of the school had to commit to be part of the INST and to work together with the teachers to solve problems such as equipment, teaching hours and resources for outdoor activities. Another aspect of this INST was supporting the teachers in their first steps of implementing new teaching methods and new contents and psychological support in order to deal with the initial resistance of the teachers towards major changes.

The data collection included qualitative and quantitative methods and was based on research tools such as questionnaires, interviews and observations. These were conducted as action research in the format of a participant observer and as a part of four PhD dissertations (Kali, 2000; Dodick, 2000; Ben-zvi-Assraf, 2003; Kapulnick, 2003) and one Master thesis (Midyan, 2003). These different studies explored all together about 1000 science teachers and their classes. Most of the studies were conducted with the junior high school level, but also included teachers and students from the elementary and the high school levels.

In addition to the teachers and the students the different studies covered other components and processes of the reform system such as principals, superintendents, curriculum developers, the academic science education establishment, the ministry of education establishment, in-service training programs and pre-service teachers programs.

4. RESULTS

It was found that the initial attitudes of most of the science teachers were positive towards the goals and teaching methods, which are related with the "Science for all" approach. However, at the same time, most of them were uncertain and some even presented negative attitudes towards four aspects of the science for all reform namely the integration of science, technology and society together; Conducting "out of classroom learning"; Combining the computer as a significant learning tool; Integrating the earth sciences as an integral part of the new curriculum.

It was found that most changes during and following the training program in the regional centers were expressed by replacing previous books with new books, while all the four aspects mentioned above remained unclear to the teachers during all three years of the training program, no matter in what program they participated and in which center the program took place. Moreover, the attitudes of those teachers were not found to be altered by their teaching experience, background, gender and their training levels in the regional centers.

The visits and observations of the above population of teachers indicated a gap between their declared practice as expressed in their questionnaires and

interviews and their actual practice in classrooms. This gap was especially clear in regard to their implementation of new teaching methods and new topics (subject matter).

The initial attitudes of the teachers who participated in the in-school long-term INST program were very similar to the other group of teachers. However, a meaningful change was found among them in relation to both their attitudes and the in practice implementation of new teaching methods and new topics (subject matter). These changes were remarkably found in their adoption of earth systems based learning materials and the use of the outdoor as a learning environment.

The study identified three factors, which are involved in the current difficulties of implementing the new reform: the science teachers, the science education leaders and the bureaucrats and politicians who lead the Ministry of Education.

In addition to the difficulties of the teachers to implement new teaching methods and to deal with new scientific topics, the interviews with the teachers revealed four additional factors, which prevent them from a genuine implementation of a new reform. These factors are: (a) an apprehension for changes (b) their feeling that the INST that took place in the out of school regional centers environments did not provide them with practical tools that can help them to overcome their apprehension of moving towards the unknown. (c) The luck of support that they have from the school management, which did not provide them the needed resources for adapting new teaching strategies such a laboratory equipment, computers, a reasonable number of students for working in a laboratory, resources for using the outdoor learning environment and reasonable amount of teaching hours. And (d) A double standards messages from the Ministry Education in general and more specifically from their science education inspectors. The teachers claimed that they were confused, since on one hand the Ministry of Education initiated the reform and their inspectors encourage and push them to participate in the regional centers' INST program, but at the same time the Ministry of Education do not provide them with the needed resources and the inspectors implemented a national testing regime, which was the antithesis of the new "Science for All" approach. Many teachers also claimed that they feel that their inspectors do not really favor the new reform. In the teachers' meetings the inspectors use the slogans and the "buzz words" of the new paradigm, but when it comes to concrete practical issues, those teachers feel that they still hold the perceptions of the former paradigm, which they grew up on.

4. DISCUSSION AND CONCLUSIONS

The findings above definitely suggest that the "Science for All" reform is not just a professional development for the Israeli science teachers. For them it is a paradigm shift and many (actually most) cannot or do not really want to undergo such a huge change. There are two main inhibitions that prevent science teachers from making such a change. One inhibition is their professional background. The author, is well aware of the apolitically correctness of such statement and therefore it is very important to make clear that the teachers themselves are not to blame. They

themselves are victims of the system where they grew up as students and teachers. Actually, the teachers are a product of a vicious circle. This circle started a long time ago with their school teachers who had poor teaching skills, continued with their pre-service training that did not provide them with a powerful and effective modeling of teaching. Thus the continue to imitate their school teachers. Unfortunately, the out of school INST model was also ineffective, since it did not provide the teachers with the practical support and the psychological support they needed to break this vicious circle.

Our findings suggest that the in-school INST model is more effective in conducting professional change when it includes the following components:

1. At the first stage the teachers have to experience the new methods and contents as learners. Positive experiences as learners will help both to be convinced of the effectiveness of the new paradigm and later to deal with their students' learning difficulties on the basis of their difficulties that they experienced as learners.
2. The school's management should be an integral part of the INST and to take the commitment for facilitating the implementation of the new reform.
3. The first teaching experiences of the new methods of contents should be done with a close support of the INST experts.
4. The INST leaders should be equipped with psychological knowledge and skills to deal with reservation and oppositions, which are the result of a change fear.

Our findings also suggest that even the most powerful and effective INST alone cannot guarantee a long-term sustainable reform. Unfortunately, education in Israel (as in many other countries) is controlled by economic and political decisions and not by pedagogical decisions. Thus, in order to lead the teachers to such a paradigm shift a lot of resources should be invested during a long period of at least ten years. However, in addition to the policy makers unwilling to allocate the needed resources, a genuine conceptual change cycle is much longer than a political cycle (the time from election to election). Therefore, the process never comes close to maturation.

It is suggested that the heart of the problem is the science education leadership. This leadership has the duty to educate the teachers and to convince the Ministry of Education to invest the needed resources. Thus, the failure of the science education reforms is primarily the failure of the science education leadership. The following reasons might be suggested as the main cause for this long-standing failure:

1. Many leaders never served as science teachers or they did it many years ago. So they can say what should be done, but they cannot show how to do it.
2. Many science educators do not have the social/psychological knowledge and skills needed to lead human beings towards a major change.
3. There are great models of professional development, but their effectiveness is too local. It seems that we are more successful to enhance professional development with professionals. Thus, unless we realize that most of our target population is not professional, we will continue to miss our target.
4. The development and maintenance of the science education establishment is heavily dependent on constant reforms' regime.
5. Most of the academic leaders grew up and based their career on the previous paradigm. Many of them fail to lead a genuine paradigm shift because of the following reasons:

- Some jumped on the wagon, but without genuine internalization of the meaning of the slogans such as "educating the future citizens", "science for all" etc.
- Some cynically use the new slogans for perpetuating what they really believe and
- Some do not believe in the new paradigm and therefore become as a Trojan horse for its failure.

It is very important to note that the author of this chapter does not blame any of the above groups namely teachers, academic science educators, the Ministry of Education bureaucrats and policy makers for sabotaging the reform. However, it is to analyze this situation not by cognitive psychology, tools, but through psychoanalysis tools. According to the psychoanalysis many aspects of the individual's behavior is controlled by her/his subconscious and by his/her conscious. Moreover, it is also well known amongst psychologists that it is very difficult to promote changes amongst individuals. According to some psychological approaches the first step for change is the understanding of the gains of resisting the change and holding to old behavior. So, what might be the gain of the three above groups of investing so much money and energies for decades in talking and walking towards the long awaited change but not getting there?

Science educators (academy): The development and maintenance of the science education establishment is heavily depended on constant reforms' regime.

Teachers: They agree that changes are needed, but not from their end. There is a huge gain in the stand that if everything is against me (Ministry of education, principals, students, parents), what ever I could do in my class is a great achievement. It is not my fault and therefore it is not my responsibility. For them to admit that they need to change means that they take responsibility of what happened in their classes. A responsibility is a huge burden and leaving without a responsibility is a huge gain.

Policy makers/politicians: The most common way for a politician to show success is by making reforms. By that they transmit two messages: a) Look, we are doing something and b) we fix the faults of the previous Minister – they are the responsible of the problems that we have today, so please be patient since fixing all their faults will take time.

There is no doubt that this chapter is far beyond being politically correct. However, everything that appeared above is based on solid data. It is time for the science education establishment to look into the mirror and to take responsibility for the almost 50 years of failing reforms. In order to implement a reform we should adopt and internalize the following elements:

1. To stop the "Dissonance" syndrome and to face and internalize the reality.
2. To consider teaching as a real profession.
3. To bridge the gap between theory and practice.
4. To adopt a system approach for teachers' professional change.

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APPENDIX A: FRAMEWORK FOR EARTH SYSTEMS EDUCATION

Understanding #1: Earth is unique, a planet of rare beauty and great value.

- $ The beauty and value of Earth are expressed by and for people through literature and the arts.
- $ Human's appreciation of planet Earth is enhanced by a better understanding of its subsystems.
- $ Humans manifest their appreciation through their responsible behavior and stewardship of subsystems.

Understanding #2: Human activities, collective and individual, conscious and inadvertent, affect planet Earth.

- $ Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.
- $ Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- $ When considering the use of natural resources, humans first need to rethink their lifestyles, then reduce consumption, then reuse and recycle.
- $ By-products of industrialization pollute the air, land, and water, and the effects may be global as well as near the source.
- $ The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

Understanding #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- $ Biologists, chemist, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- $ Direct observation, simple tools, and modern technology are used to create, test and modify models and theories that represent, explain, and predict changes in the Earth system.
- $ Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- $ Scientific study may lead to technological advances. Regardless of sophistication, technology cannot be expected to solve all of our problems.
- $ The use of technology may have benefits as well as unintended side effects.

Understanding #4: The Earth system is composed of interacting subsystems of water, rock, ice, air, and life.

- $ The subsystems are continuously changing through natural processes and cycles.
- $ Forces, motions and energy transformations drive the interactions within and between the subsystems.
- $ The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- $ Each component of the Earth system has characteristic properties, structure, and composition that may be changed by interactions of subsystems.
- $ Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- $ Weathering, erosion, and deposition continuously reshape the surface of the Earth.
- $ The presence of life affects the characteristics of other systems.

Understanding #5: Planet Earth is more than 4 billion years old and its subsystems are continually evolving.

- $ Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.

$ Materials making up planet Earth have been recycled many times.
$ Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
$ Evolution is a theory that explains how life has changed through time.

Understanding #6: Earth is a small subsystem of a solar system within the vast and ancient universe.

$ All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
$ All bodies in space, including Earth, are influenced by forces acting throughout the Solar System and the universe.
$ Nine planets, including Earth, revolve around the sun in nearly circular orbits.
$ Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
$ The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
$ The rotation of Earth on its axis determines day and night.
$

Understanding #7: There are many people with careers that involve study of Earth's origin, processes, and evolution.

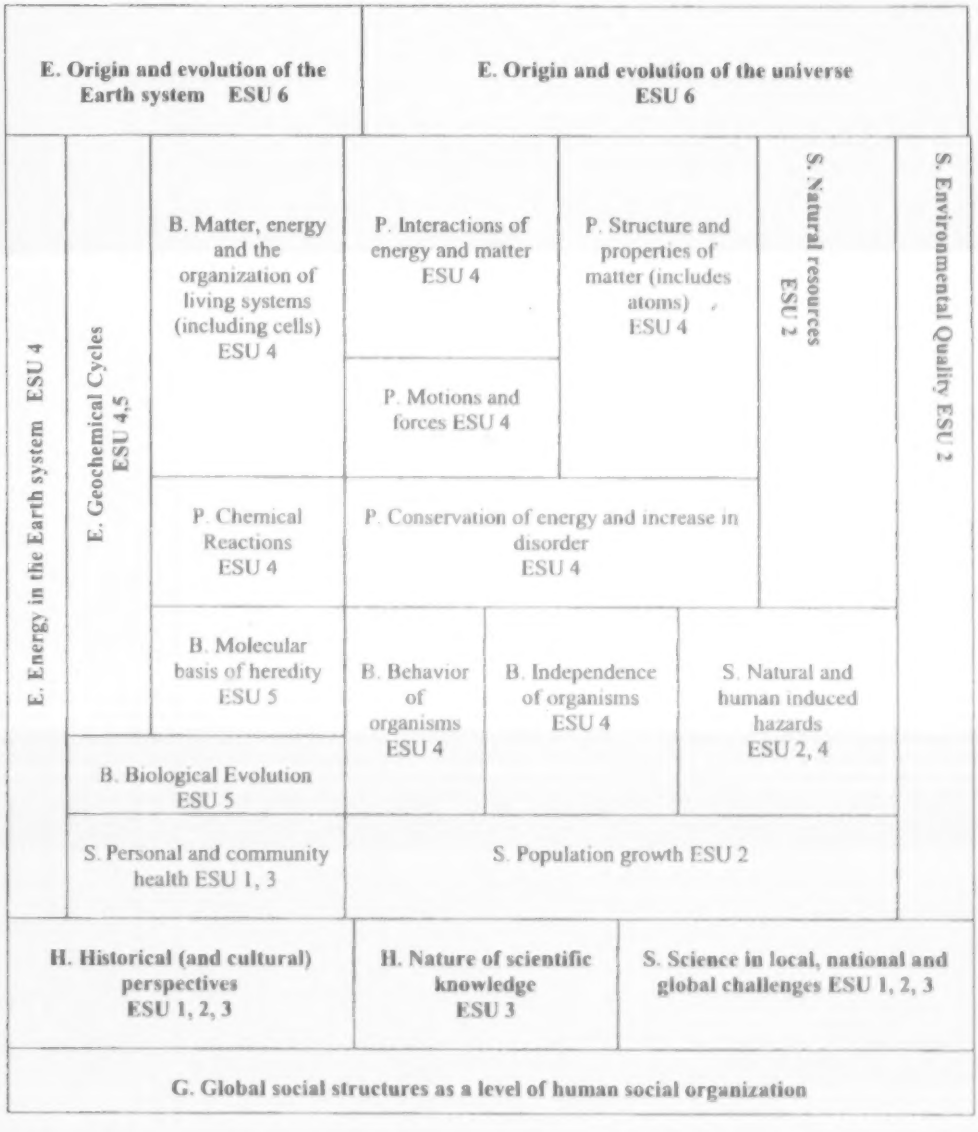
$ Teachers, scientists, and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
$ Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
$ Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
$ Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
$ Many people pursue avocations related to planet Earth processes and materials.

APPENDIX B: GLOBAL SCIENCE LITERACY CURRICULUM FRAMEWORKS

Middle School

<table>
<tr><td colspan="6">E. Structure of the Earth system ESU 4</td></tr>
<tr><td rowspan="3">E. Earth in the Solar system ESU 6</td><td>B. Structure and function of living systems ESU 4</td><td colspan="2" rowspan="2">P. Transfer of energy ESU 4</td><td rowspan="2">P. Properties and changes of properties in matter ESU 4, 5</td><td rowspan="3">S. Natural Hazards ESU 4</td></tr>
<tr><td>P. Motions and forces ESU 4, 6</td></tr>
<tr><td>B. Populations and ecosystems ESU 4</td><td colspan="3">B. Populations, resources and environments ESU 2</td></tr>
<tr><td rowspan="4">E. Earth's history ESU 5</td><td>B. Reproduction and heredity ESU 4</td><td rowspan="2">B. Diversity and adaptations of organisms ESU 4</td><td rowspan="2">B. Regulation and behavior ESU 4</td><td rowspan="2">S. Personal health ESU 1, 2, 4</td><td rowspan="3">S. Risks and benefits ESU 2, 7</td></tr>
<tr><td>H. History of science ESU 3</td></tr>
<tr><td>H. Nature of science ESU 3</td><td colspan="3">S. Science and technology in society ESU 2, 3, 7</td></tr>
<tr><td>G. Humankind as an entity interconnected across space and time ESU 4, 5, 6</td><td colspan="4">G. Earth, humankind's ecological and cosmic home ESU 1, 4</td></tr>
</table>

Possible organization of science standards and global education objectives for use in developing middle school (years 6 to 9) science curricula. Letters at the beginning of each standard identify the group it belongs to (refer to Figure 1) except for "G". It identifies global education objectives.


E. Origin and evolution of the Earth system ESU 6
E. Origin and evolution of the universe ESU 6
E. Energy in the Earth system ESU 4
E. Geochemical Cycles ESU 4,5
B. Matter, energy and the organization of living systems (including cells) ESU 4
P. Interactions of energy and matter ESU 4
P. Structure and properties of matter (includes atoms) ESU 4
P. Motions and forces ESU 4
S. Natural resources ESU 2
S. Environmental Quality ESU 2
P. Chemical Reactions ESU 4
P. Conservation of energy and increase in disorder ESU 4
B. Molecular basis of heredity ESU 5
B. Behavior of organisms ESU 4
B. Independence of organisms ESU 4
S. Natural and human induced hazards ESU 2, 4
B. Biological Evolution ESU 5
S. Personal and community health ESU 1, 3
S. Population growth ESU 2
H. Historical (and cultural) perspectives ESU 1, 2, 3
H. Nature of scientific knowledge ESU 3
S. Science in local, national and global challenges ESU 1, 2, 3
G. Global social structures as a level of human social organization

A possible organization of science standards and global education objective for high school (years 10 through 12) science curricular development. Letters in front of the topic indicate the group of standards topic is related (refer to Figure 1) to except for the letter 'G'. It indicates a global education objective. The code ESU indicates the Earth Systems Education Understanding the topic is related to.

CONTRIBUTING AUTHORS

Maan Jiang Broadstock is former Associate Professor of Education at the Tainan National University, Taiwan and Research Associate in Physics Education at Wittenberg University, USA. Currently she is raising two sons.

Celso D.R. Carneiro is Professor at the Geosciences Institute of the University of Campinas, Brazil. He is a research geologist in the institute coordinating many projects of geological mapping, structural analysis, mineral prospecting, basin studies, geomorphological and geological regional compilations in many areas of the country. He offers graduate courses in Introductory Geoscience, Structural Geology and several post-graduate courses. He is author or co-author of diversified didactic material.

Chun-Yen Chang is Professor in the Department of Earth Sciences at the National Taiwan Normal University, Taipei, Taiwan. His major research interests include problem-solving models, inquiry teaching, computer-assisted instruction, and pedagogical understandings and conceptual change instruction in the area of earth science education. He has recently conducted a series of studies involving the implementation of GSL-inspired curriculum or instructional modules in Taiwan.

Maurício Compiani is Assistant Professor at the Institute of Geosciences at the University of Campinas, Brazil. He has been working on geological education, issues related to the importance of fieldwork and visual representation in education, and teachers in-service training. He coordinated the 5-year project "Geosciences and teachers on-service training within the public school in Campinas (São Paulo, Brazil)".

C.P. Constantinou, is program leader for the Learning in Physics Group in the Department of Educational Sciences at the University of Cyprus, Nicosia.

Silvia Figueirôa is Associate Professor at the Institute of Geosciences at the University of Campinas, Brazil. She has been working on the history of geological sciences, and on the relations between history of sciences and science education. She actively participated in the 5-years project "Geosciences and teachers on-service training within the public school in Campinas (São Paulo, Brazil)".

Rosanne W. Fortner is a professor of Environmental Science Education at The Ohio State University. A co-founder of the Earth Systems Education Program in the early 1990s, she has coordinated the publication of 12 books of curriculum activities with an ESE emphasis and now teaches graduate courses for teachers using the materials and methods that foster Global Science Literacy. Her chapter is derived from work begun as a Fulbright Senior Scholar in Cyprus.

Pedro Wagner Gonçalves is a Professor in the Department of Teaching Applied for Geoscience (Institute of Geoscience at State University of Campinas). He teaches courses on teaching methods and geoscience. His main interests are in writing and

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research on James Hutton, his life and works and on the development of teachers for Geoscience.

Chan-Jong Kim is Associate Professor in Cheongju National University of Education, Korea. His research interests include the instructional approaches based on the nature of earth science, portfolio assessments in elementary science classroom and informal science learning in natural history museums. He wrote science textbooks for elementary, junior high, and high school students in Korea. He also wrote several books in the area of earth science, science education methods and science performance assessments.

Sylke Hlawatsch works at the Leibniz-Institute for Science Education (IPN) in Kiel, where she manages the project "System Earth" and develops teaching material based on research on students' preconceptions, students' system thinking abilities as well as the implementation of earth science topics in the German school system.

Lee Tan Wee Hin holds the concurrent appointments of Director of the National Institute of Education, Professor of Biological Sciences in Nanyang Technological University, and President of the Singapore National Academy of Science. His research interests are in the fields of marine biology, science education, museum science, telecommunications, and transportation. More recently, he has also started studying how attributes of problem-solving, creative thinking and independent can be fostered in students through the use of Global Science Literacy tenets.

Hyonyong Lee recently received his Doctorate in Science Education at The Ohio State University with an emphasis of science curriculum integration through the Earth systems approach. His current research concerns implementing Earth systems education curricula in Korea, development of Earth systems oriented science methods and web-based education and development of web-based instructional materials and resources for Global Science Literacy and Earth Systems Education.

José Lillo is Professor of Science Education in the Faculty of Education in Vigo University, Spain. He has participated in a number of integrated science education studies for primary and secondary education supported by UNESCO. From 1993 to 2002 he coordinated The Curriculum Development on Geology and Earth and Environmental Sciences in the Galician Community (NW of Spain).

Victor J. Mayer is Professor Emeritus at The Ohio State University. He has had a long career in teacher education and the earth sciences. Since his retirement in 1995 he has worked to provide international leadership in the development and implementation of curriculum philosophy behind Earth Systems Education and Global Science Literacy.

Luis Marques is Associate Professor at the University of Aveiro, in charge of earth sciences education. He is involved in different national and international research projects in the area of science education, particularly related to practical work, outdoors education and designing and assessment of science curriculum materials.

Robert J. Myers is a senior instructional designer and program manager at the NASA Classroom of the Future, Wheeling Jesuit University. He specializes in problem-based and online learning. He is the team leader on the Exploring the Environment series, http://www.cotf.edu/ete, as well as the Earth System Science Education Alliance featuring online teacher professional development in Earth system science.

Nir Orion is Professor in the Department of Science Education of the Weizmann Institute of Science, Israel. He leads a research team studying the implementation of the various aspects of Earth Systems Science curricula in Israeli schools.

Eric M. Riggs is Assistant Professor in the Department of Geological Sciences and conducts his research through the Center for Research in Mathematics and Science Education, San Diego State University, USA.

R. Subramaniam is an Assistant Professor at the National Institute of Education in Nanyang Technological University. His research interests are in the fields of physical chemistry, science education, theoretical cosmophysics, museum science, telecommunications, and transportation.

Roger Trend spent a decade teaching geography and geology at the 11 - 18 years, followed by a decade teaching the same subjects at the 16 - 18 level and then another decade teaching and researching at the University of Exeter, UK. His main research focuses within geoscience education are (i) implications for geoscience teaching of links between geography and science teachers at school level and (ii) people's understanding of geological time across UK society.

Jiang Yu, a native of the People's Republic of China, is an associate professor of physics at Fitchburg State College in Massachusetts, USA. Her research is concentrated on the studies of concept learning of physics at the college level as well as science literacy education for the general public. She is an active member in the American Association of Physics Teachers promoting science learning for all people with a conceptual and cultural appreciation.

Implementing Global Science Literacy

Edited by
Victor J. Mayer

This book follows the publication of *Global Science Literacy* (2002) by Kluwer Academic Publishers. It expands on the arguments for a new type of science curriculum in that book for the secondary schools of the world. Instead of being based on each of the major disciplines as are almost all current science curricula, it suggested that curricula should be conceptually organized around the Earth system, include the science methodology of the system sciences, and capitalize on the cross-cultural characteristics of science to assist in establishing greater understanding of the contributions of all cultures. The first several chapters of the present book add additional support to Global Science Literacy (GSL) as a viable international basis for science curricula. Chapters describe the characteristics of Chinese culture and compares them to GSL characteristics, discuss research on science in an indigenous culture and the implications for GSL, and summarize research on science teaching in the field and its implications for GSL. Additional chapters describe national science curricula of Taiwan, the Peoples Republic of China, Singapore, Korea, Germany and Spain and the conditions for implementing GSL in those countries. The last several chapters describe experiences and programs for developing teachers of Earth Systems Education curricula and those based on Global Science Literacy. Over twenty individuals from twelve different countries contributed their expertise to the chapters in this book.

The illustration on the front cover is from the National Aeronautics and Space Administration. It depicts a young John Glenn looking at the Earth through a celestial globe during his astronaut training. Glenn represents the best of a global citizenry. He served as a Marine Corps pilot, became the first astronaut to circle the Earth, went on to become a Senator from Ohio, and became the oldest active astronaut flying his last mission at age 77. He now serves at The Ohio State University in the John Glenn Institute for Public Service and Public Policy. He has received many honors. One of the most significant for his inclusion on the cover of this book was the receipt of the first outstanding service to science education award of the Science Education Council of Ohio, the organization of Ohio's science teachers. This award recognized his support of quality science education while serving as a Senator from the State. We would hope that science curricula and teaching in the future will inspire in students a love of science, the Earth it studies, and the people of all countries that inhabit Earth commensurate with that exhibited by John Glenn throughout his life. We believe that Global Science Literacy can be the foundation for such curricula and teaching.

Earth Systems Education Program
The Ohio State University
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Sign here, → please

Signature: Victor J Maher

Printed Name/Position/Title: VICTOR J. MAHER Prof Emeritus

Organization/Address: The Ohio State University 125 So Oval Drive, COS OH

Telephone: 614-267-3094 FAX: Same

E-Mail Address: maher.40@osu.edu Date: March 13, 2003